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Predicting Adherence to Complex Health Regimens in Women with Chronic Illness: A Random Forest Approach Integrating Health Literacy and Self-Efficacy

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A B S T R A C T

Objective: This study aimed to predict adherence to complex health regimens in women with chronic illnesses by evaluating the integrated predictive value of health literacy, self-efficacy, and sociodemographic factors using a Random Forest machine learning approach.

Methods and Materials: A multicenter cross-sectional study was conducted among 482 women with chronic illnesses recruited from referral hospitals in Jakarta and Surabaya, Indonesia. Data were collected via structured interviews utilizing validated tools, including the General Medication Adherence Scale ($\alpha = 0.84$), the Health Literacy Questionnaire ($\alpha = 0.88$), and the Chronic Disease Self-Efficacy Scale ($\alpha = 0.91$). A Random Forest regression algorithm, optimized via grid search hyperparameter tuning on a 70/30 train-test split, was utilized to evaluate predictive accuracy and rank feature importance.

Findings: The optimized Random Forest model (250 trees, maximum depth of 15) successfully explained 74% of the variance in regimen adherence ($R^2 = 0.74$), demonstrating high accuracy with a Mean Absolute Error of 1.85 and a Root Mean Squared Error of 2.42. Feature importance analysis (measured by Gini impurity) revealed that the strongest predictors were self-efficacy in symptom control (0.185), health literacy in understanding information (0.142), self-efficacy in communicating with physicians (0.128), and health literacy in actively engaging with providers (0.115), heavily outperforming static sociodemographic factors such as age, income, and educational attainment.

Conclusion: Adherence to complex health regimens is predominantly driven by modifiable psychological and cognitive assets—specifically symptom-management self-efficacy and health information comprehension—rather than static sociodemographic characteristics.

Keywords: *regimen adherence, chronic illness, health literacy, self-efficacy.*

1. Introduction

The global prevalence of chronic diseases presents a formidable and escalating challenge to modern healthcare systems, necessitating a fundamental paradigm shift from acute, episodic interventions to continuous, long-term, and patient-centered disease management. For individuals grappling with chronic conditions such as cardiovascular disease, type 2 diabetes mellitus, and autoimmune disorders, daily existence is inextricably linked to the execution of highly complex health regimens. These multifaceted therapeutic regimens typically encompass rigid pharmacological schedules, stringent dietary and nutritional modifications, continuous physiological symptom monitoring, and significant behavioral and lifestyle adjustments. The prediction of self-care behaviors and the subsequent quality of life experienced by these patients is heavily reliant on an individual's cognitive perception of their disease and their intrinsic capacity to integrate these exhaustive, multifaceted tasks into their daily routines (Eydi et al., 2020). This requirement is particularly salient in the post-pandemic landscape, where environmental and societal factors associated with maintaining a health-promoting lifestyle have been significantly disrupted, thereby demanding greater psychological resilience and adaptability from both adult and older adult populations managing long-term health conditions (Suksatan et al., 2022). Furthermore, underlying psychological capital and the application of targeted motivational interviewing interventions play a critical role in shaping the lifestyle choices and long-term adherence behaviors of populations managing severe metabolic conditions (HosseiniTavan et al., 2023). Women, in particular, often navigate these protracted chronic illness trajectories while simultaneously managing disproportionate psychosocial, familial, and socioeconomic stressors. These unique gendered burdens can profoundly influence their cognitive bandwidth, psychological reserves, and ultimate adherence to prescribed life-sustaining therapies.

A foundational determinant of successful chronic disease self-management is health literacy. Health literacy is broadly defined as the cognitive and social skills that determine the motivation and functional ability of individuals to gain access to, comprehensively understand, and actively utilize information in ways that promote and maintain optimal health. Current empirical research consistently highlights the profound impact of health literacy on physical and psychological health outcomes among older patients suffering from chronic diseases, often demonstrating its effects through complex moderated mediation models that encompass self-care behaviors and adaptive coping mechanisms (Lu et al., 2023). Low health literacy is globally recognized as a formidable clinical barrier, directly correlating with an increased symptom burden, poor medication adherence, elevated rates of hospitalization, and higher overall mortality. This dynamic is further complicated by the chain mediating role of social support systems and yielding coping styles, which can either mitigate or severely exacerbate the negative effects of limited health literacy on vulnerable patients grappling with life-limiting conditions such as chronic heart failure (Yan et al., 2025). Additionally, the rapid evolution and digitization of healthcare delivery have underscored the critical nature of electronic health literacy. This specific technological proficiency significantly influences chronic disease self-management by dictating an adult patient's ability to seamlessly navigate complex digital patient portals, discern reliable online medical information from misinformation, and utilize telehealth services effectively (Osokpo, 2025).

Despite the unequivocal clinical need for adequate health literacy among chronic disease populations, systemic interventions designed to improve it—particularly in the context of complex, multi-systemic conditions like chronic kidney disease—often yield variable and inconsistent results, thereby highlighting the urgent need for highly tailored, context-specific, and culturally sensitive educational strategies (Campbell et al., 2022). The profound influence of health literacy extends far beyond the mere mechanical comprehension of medical instructions; it deeply shapes an individual's fundamental illness perceptions and their core beliefs regarding medication efficacy. For instance, among cohorts of patients diagnosed with chronic obstructive pulmonary disease, lower health literacy is strongly and independently associated with fatalistic illness beliefs and deep-seated skepticism regarding the absolute necessity of daily maintenance medications (Kale et al., 2015). The broader socio-ecological and cultural context must also be rigorously considered, as culture plays an indispensable, underlying role in shaping health literacy paradigms. Cultural backgrounds heavily influence how minority and immigrant populations engage with chronic disease screening protocols, interpret nuanced medical advice from practitioners, and navigate historically complex western healthcare systems (Shaw et al., 2008). Furthermore, the reverberations of health literacy are undeniably intergenerational; the functional health literacy levels of parents or primary caregivers have a profound,

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globally documented impact on the long-term health outcomes, regimen adherence, and developmental trajectories of children and dependents managing chronic diseases (Zaidman et al., 2023).

While health literacy provides the necessary cognitive and informational framework for understanding a prescribed health regimen, self-efficacy provides the crucial psychological catalyst required to actually execute and sustain it. Rooted in Bandura's social cognitive theory, self-efficacy refers to an individual's unwavering belief in their innate capacity to achieve specific goals, overcome prominent barriers, or successfully execute the behaviors necessary to produce specific performance attainments. In the demanding context of chronic disease, self-efficacy operates as a robust, independent predictor of spiritual health and overall psychological well-being, particularly among middle-aged and older adult populations facing the existential realities of physical decline (Chen, 2023). The subjective confidence a patient firmly holds in their ability to autonomously manage their condition can even serve as a psychological buffer against severe existential distress. For example, empirical evidence demonstrates that higher levels of self-efficacy inversely correlate with the manifestation of death anxiety in individuals suffering from the suffocating progression of advanced chronic obstructive pulmonary disease (Güçlü & Akça, 2024).

The clinical synergy between disease-management self-efficacy and health literacy is absolutely vital for effective, long-term self-management. Qualitative investigations into patient and professional perspectives on specific lifestyle modifications, such as the role of daily nutrition in chronic respiratory disease management, vividly reveal that foundational food and nutrition literacies must be intimately coupled with the psychological self-efficacy to actually implement and sustain those dietary changes in the home environment (Hakami et al., 2018). Furthermore, comprehensive studies focusing on marginalized patients with chronic kidney disease demonstrate that while external social support and internal health literacy collectively empower patients, their positive downstream effects on tangible clinical outcomes are heavily mediated by the patient's underlying self-efficacy to aggressively manage the multifaceted demands of their illness (Chen et al., 2018). Without robust self-efficacy, even the most exceptionally health-literate individual may falter and demonstrate non-adherence when inevitably faced with the daily physical fatigue, profound emotional taxation, and logistical hurdles characteristic of a complex therapeutic regimen.

A pervasive, debilitating, and severely complicating factor in the management of complex chronic illnesses is the chronic presence of physical pain, which fundamentally alters a patient's baseline capacity for regimen adherence. Pain-related emotional distress is intimately and inversely linked to cognitive factors; notably, diminished health literacy is significantly associated with higher reported levels of chronic pain severity and subsequent pain-related psychological distress (Miller-Matero, 2024). Within this specific clinical domain, pain self-efficacy—defined as the enduring belief in one's ability to carry out routine daily activities and maintain a reasonable quality of life despite experiencing moderate to severe pain—emerges as a highly critical psychological protective mechanism. Advanced structural modeling of pain self-efficacy, particularly when evaluated alongside health-oriented lifestyle behaviors, reveals that high self-efficacy effectively mitigates overwhelming feelings of clinical helplessness and emotional despair in severe chronic pain populations (Mohammadi et al., 2021).

The crucial mediating role of pain self-efficacy is consistently documented across diverse somatic manifestations of chronic illness. It serves as a vital cognitive buffer between the raw physiological sensation of pain and the patient's subsequent psychosocial adjustment, heavily influencing how individuals process maladaptive pain catastrophizing and the debilitating fear of movement, as frequently observed in degenerative rheumatoid arthritis populations (Barzegari Sultan Ahmadi, 2021). Furthermore, the established relationship between underlying psychosocial vulnerabilities and patient-reported functional disability is largely, if not entirely, dictated by the degree of pain self-efficacy a patient possesses (Varela & Van Asselt, 2022). Even when controlling for highly diverse clinical histories and baseline demographic characteristics, pain self-efficacy remains a predominant and statistically significant determinant of functional independence for chronic disease patients undergoing rigorous occupational and rehabilitative therapies (Terzaki et al., 2023). Psychological interventions aimed at actively fostering self-compassion can successfully reduce overall pain disability, but this therapeutic reduction is fundamentally mediated by parallel enhancements in the patient's future self-identification and, crucially, their disease-management self-efficacy (Mistretta et al., 2023). Consequently, multifaceted integrative interventions that seamlessly combine clinical education, targeted physical therapy, and mind-body practices such as yoga are highly successful largely because they actively induce measurable,

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positive neurocognitive changes in pain self-efficacy, adaptive coping skills, and the reduction of fear-avoidance beliefs (Marshall et al., 2022).

The contemporary scientific literature unequivocally establishes that health literacy, self-efficacy, chronic pain profiles, and baseline sociodemographic variables do not operate in isolated, independent silos; rather, they interact dynamically through highly complex, interwoven, and often bidirectional pathways. For instance, the intricate relationship between broad psychological constructs, such as the Big Five personality traits, and foundational health literacy in elderly chronic disease patients is heavily mediated by dynamic intermediary variables including family communication structures and, prominently, disease-specific self-efficacy (Zhang et al., 2024). Traditional statistical methodologies utilized in medical research, such as linear regression modeling or standard structural equation modeling, while highly valuable for identifying broad, independent associations, frequently fall short of capturing the highly non-linear, multidimensional interactions inherent in human behavioral psychology and medical adherence. This distinct methodological gap necessitates the immediate application of advanced computational techniques capable of deciphering these complex webs of psychological influence. Machine learning algorithms, particularly robust ensemble methods like the Random Forest approach, offer a highly sophisticated and precise alternative. By constructing multitudes of predictive decision trees, Random Forest algorithms can autonomously detect intricate interaction effects, subtle behavioral threshold dynamics, and the precise relative importance of distinct psychological and sociodemographic features without the restrictive mathematical assumptions of strict linearity or normal data distribution.

Despite the widely acknowledged clinical importance of these psychological constructs, there remains a critical, unaddressed paucity of research leveraging advanced machine learning algorithms to holistically predict how specific, nuanced sub-domains of health literacy and disease-management self-efficacy interact to drive actual adherence to complex medical regimens, specifically among highly burdened populations of women with chronic illnesses. Addressing this specific literature gap is absolutely essential for the future development of highly targeted, personalized, and efficient clinical interventions designed to optimize female patient outcomes in increasingly strained global healthcare systems. Therefore, the aim of this study is to utilize a Random Forest machine learning approach to predict adherence to complex health regimens in women with chronic illnesses by evaluating the integrated, non-linear predictive value of health literacy, disease-management self-efficacy, and sociodemographic factors.

2. Methods and Materials

2.1. Study design and Participant

This study utilized a multicenter, cross-sectional predictive design to investigate the interrelated factors influencing regimen adherence among female patients. The research was conducted across four major public referral hospitals located in Jakarta and Surabaya, Indonesia, capturing a diverse demographic and socioeconomic cross-section of the urban and peri-urban population. The target population comprised adult women diagnosed with at least one chronic illness requiring a complex therapeutic regimen, defined in this context as the concurrent management of multiple prescribed medications, dietary modifications, and regular physical therapy or symptom monitoring. Through a purposive sampling technique, an exact total of 482women were recruited over an eight-month period. To be eligible for inclusion, participants had to be adult females aged eighteen years or older, formally diagnosed with a qualifying chronic condition such as type 2 diabetes mellitus, cardiovascular disease, or an autoimmune disorder for a minimum duration of six months, and capable of reading and communicating fluently in Bahasa Indonesia. Patients were excluded from the study if they presented with documented severe cognitive impairments, acute psychiatric disorders, or terminal illnesses that would preclude their ability to independently manage their health regimens or provide informed consent.

2.2. Measures

Data were gathered utilizing a comprehensive, structured questionnaire administered via face-to-face interviews by trained bilingual research assistants. The survey instrument was composed of four distinct sections designed to capture sociodemographic variables, treatment adherence, health literacy, and self-efficacy. Sociodemographic and clinical characteristics, including age, educational attainment, monthly household income, marital status, and duration of illness, were collected using a standardized demographic intake form. To measure the primary outcome variable of adherence to complex health regimens, the study employed the validated Indonesian translation of the General Medication Adherence Scale. This tool evaluates behaviors

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related to medication intake, dietary compliance, and lifestyle modifications, yielding a continuous score where higher values represent stricter adherence, demonstrating robust internal consistency with a Cronbach's $\alpha$of 0.84in the current sample. Health literacy was quantified using a culturally adapted version of the Health Literacy Questionnaire, which assesses the multidimensional construct of health literacy across domains such as finding, understanding, and actively utilizing health information. Participants responded on a Likert-type scale, and the instrument exhibited high reliability with an αcoefficient of 0.88. Finally, disease-management self-efficacy was evaluated using the Chronic Disease Self-Efficacy Scale. This established instrument measures a patient's confidence in performing specific tasks related to their illness, such as controlling symptoms, communicating with physicians, and managing emotional distress. The items were scored on a ten-point confidence scale, with the aggregated mean score serving as the global self-efficacy index, which showed excellent internal consistency in this study cohort at $\alpha = 0.91$.

2.3. Data Analysis

The collected data were subjected to rigorous computational analysis using the Python programming language, specifically leveraging the Scikit-Learn library for machine learning implementation. Initial data preprocessing involved screening for missing values, which were addressed using predictive mean matching imputation given that the missingness accounted for less than 3%of the total dataset. Continuous variables were standardized using Z-score normalization to ensure that features with inherently different scales contributed equally to the model, while categorical sociodemographic variables were transformed using one-hot encoding. To predict adherence levels, a Random Forest regression algorithm was deployed due to its high accuracy, robustness against overfitting, and ability to capture non-linear interactions between complex psychological and sociodemographic variables. The dataset of 482participants was randomly partitioned into a training set comprising 70%of the data and a testing set containing the remaining 30%. Model optimization was achieved through extensive hyperparameter tuning using a grid search with five-fold cross-validation, optimizing parameters such as the number of estimators, maximum tree depth, and minimum samples required to split an internal node. The predictive performance of the final optimized Random Forest model was evaluated on the unseen testing set using standard regression metrics, primarily the Coefficient of Determination (R^2), Mean Absolute Error, and Root Mean Squared Error. Furthermore, to elucidate the specific contributions of health literacy and self-efficacy relative to other variables, feature importance was calculated using the Gini impurity reduction method. This allowed the research team to rank all predictive variables based on their relative influence on the model's accuracy, providing deep clinical insights into which specific facets of self-efficacy and health literacy are most critical for driving adherence. All accompanying descriptive statistics and preliminary bivariate correlations were assessed using a statistical significance threshold of $p < 0.05$.

3. Findings and Results

The findings of this study elucidate the complex interplay between sociodemographic factors, health literacy, disease-management self-efficacy, and regimen adherence among the sample of 482 Indonesian women with chronic illnesses. Initial descriptive analyses were conducted to establish the baseline sociodemographic and clinical profile of the participants. As detailed in Table 1, the sample presented a mean age of 54.3 years (SD = 8.7), indicative of a predominantly middle-aged to older adult demographic typical of chronic disease populations. A significant portion of the participants had completed secondary education (46.5%), while a smaller fraction possessed tertiary degrees (18.9%). In terms of clinical characteristics, Type 2 Diabetes Mellitus was the most prevalent primary diagnosis, affecting 44.6% of the cohort, followed by cardiovascular diseases (31.1%) and autoimmune disorders (24.3%). The duration of illness varied considerably, with the average participant having managed their primary diagnosis for 6.4 years (SD = 3.2). This extended duration of illness highlights the chronicity of their conditions and the sustained requirement for complex regimen adherence. Further details regarding marital status and monthly household income distributions, categorized according to regional standards, are comprehensively presented in the accompanying table, demonstrating a socioeconomically diverse urban and peri-urban sample from the Jakarta and Surabaya regional hospitals.

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Table 1

Sociodemographic and Clinical Characteristics of the Participants (N = 482)

Characteristic	Frequency (n)	Percentage (%)	Mean (M)	Standard Deviation (SD)
Age (years)			54.3	8.7
18 - 39	28	5.8		
40 - 59	312	64.7		
\ge 60	142	29.5		
Educational Attainment				
Primary or below	167	34.6		
Secondary	224	46.5		
Tertiary	91	18.9		
Monthly Household Income				
Below regional minimum	134	27.8		
Meets regional minimum	215	44.6		
Above regional minimum	133	27.6		
Primary Chronic Diagnosis				
Type 2 Diabetes Mellitus	215	44.6		
Cardiovascular Disease	150	31.1		
Autoimmune Disorder	117	24.3		
Duration of Illness (years)			6.4	3.2
0.5 - 4.9	198	41.1		
5.0 - 9.9	205	42.5		
\ge 10.0	79	16.4		

Prior to executing the predictive machine learning algorithms, baseline levels of the primary psychological constructs and the outcome variable were evaluated, alongside their bivariate relationships. The General Medication Adherence Scale revealed a mean adherence score of 23.4 (SD = 4.8) out of a maximum possible 33, suggesting moderate overall adherence within the sample, yet highlighting substantial room for improvement in managing complex regimens. The multidimensional Health Literacy Questionnaire yielded a moderate overall mean score of 3.2 (SD = 0.5) on a 5-point scale, indicating that while patients possessed foundational knowledge, many struggled with advanced health information processing. The Chronic Disease Self-Efficacy Scale demonstrated an average confidence level of 6.8 (SD = 1.4) out of 10. Pearson correlation coefficients, as displayed in Table 2, indicated highly significant, positive relationships between the independent variables and regimen adherence. Specifically, overall self-efficacy exhibited a strong positive correlation with adherence ($r = 0.62$, $p < 0.001$), while health literacy showed a moderately strong positive association ($r = 0.54$, $p < 0.001$). Notably, health literacy and self-efficacy were also significantly correlated with each other ($r = 0.48$, $p < 0.001$), justifying the use of a Random Forest approach to manage potential multicollinearity and map the non-linear interactions between these predictors.

Table 2

Descriptive Statistics and Bivariate Correlations of Key Study Variables

Variable	M	SD	1	2	3	4	5
1. Regimen Adherence (GMAS)	23.4	4.8	—				
2. Health Literacy (Overall)	3.2	0.5	0.54**	—			
3. Self-Efficacy (Overall)	6.8	1.4	0.62**	0.48**	—		
4. Age	54.3	8.7	-0.12*	-0.21**	-0.15**	—	
5. Duration of Illness	6.4	3.2	0.28**	0.19**	0.24**	0.35**	—

The predictive modeling phase utilized the Random Forest regression algorithm, trained on a randomly selected subset of 337 participants (70%) and validated on an unseen testing set of 145 participants (30%). Following rigorous hyperparameter tuning via five-fold cross-validation grid search, the optimal model architecture comprised 250 decision trees with a maximum depth of 15 and a minimum of 4 samples required to split an internal node. When applied to the unseen testing data, the optimized model demonstrated robust predictive capabilities, capturing a substantial

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proportion of the variance in complex regimen adherence. The model achieved a Coefficient of Determination (R^2) of 0.74, indicating that 74% of the variance in adherence scores could be accurately predicted by the integrated set of sociodemographic, health literacy, and self-efficacy features. The error metrics further substantiated the model's precision, yielding a Mean Absolute Error of 1.85 points and a Root Mean Squared Error of 2.42 points on the adherence scale. These low error margins confirm that the Random Forest algorithm successfully mapped the complex, non-linear dependencies among the variables, outperforming traditional linear modeling expectations and providing a highly accurate predictive framework for clinical application.

To dismantle the "black box" nature of the Random Forest algorithm and extract actionable clinical insights, a feature importance analysis was conducted using the Gini impurity reduction method. This technique isolated the distinct contributions of individual predictors, including specific sub-domains of the health literacy and self-efficacy scales. As presented in Table 3, self-efficacy related to symptom control emerged as the most critical determinant of adherence, commanding the highest importance score (0.185). This suggests that a patient's confidence in managing the physiological manifestations of their illness is the strongest driver of their compliance with complex therapies. The second most influential feature was the health literacy domain concerning the ability to understand health information (0.142), emphasizing the necessity for clear, comprehensible medical communication. Self-efficacy in communicating with physicians (0.128) and the health literacy domain of actively engaging with healthcare providers (0.115) also ranked highly, underscoring the vital role of the patient-provider dynamic. Interestingly, while sociodemographic factors like the duration of illness (0.084) and educational attainment (0.062) contributed to the model, they held substantially less predictive weight than the modifiable psychological and cognitive constructs. Age and income exhibited the lowest relative importance scores among the top predictors, indicating that when health literacy and self-efficacy are robust, the barriers typically associated with socioeconomic status and age are significantly mitigated in the context of regimen adherence.

Table 3

Random Forest Feature Importance for Predicting Regimen Adherence

Predictor Feature	Gini Importance Score	Relative Rank
Self-Efficacy: Symptom Control	0.185	1
Health Literacy: Understanding Information	0.142	2
Self-Efficacy: Communicating with Physicians	0.128	3
Health Literacy: Actively Engaging with Providers	0.115	4
Self-Efficacy: Managing Emotional Distress	0.096	5
Duration of Illness (Years)	0.084	6
Health Literacy: Navigating the Healthcare System	0.071	7
Educational Attainment	0.062	8
Age	0.043	9
Monthly Household Income	0.035	10

4. Discussion

The primary objective of this study was to elucidate the complex, multidimensional factors influencing adherence to complex health regimens among women with chronic illnesses, utilizing a robust Random Forest machine learning approach. The predictive modeling successfully demonstrated that an integrated framework comprising sociodemographic variables, health literacy, and disease-management self-efficacy could account for a substantial 74% of the variance in regimen adherence ($R^2 = 0.74$). The low error margins, specifically a Mean Absolute Error of 1.85 and a Root Mean Squared Error of 2.42, underscore the superior predictive capability of ensemble machine learning algorithms in capturing the non-linear intricacies of human health behavior compared to traditional linear statistical models. The most salient finding derived from the feature importance analysis is that modifiable cognitive and psychological constructs—predominantly self-efficacy in symptom control and the capacity to understand health information—vastly outperform static sociodemographic factors such as age, educational attainment, and household income in predicting patient compliance. This critical revelation aligns with the growing consensus in behavioral

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medicine that the cognitive perception of a disease and the intrinsic psychological capacity for self-care are the ultimate determinants of long-term health outcomes and quality of life (Eydi et al., 2020).

The emergence of self-efficacy related to symptom control as the absolute strongest predictor of regimen adherence highlights the profound daily burden experienced by women managing chronic conditions. For patients grappling with complex illnesses, the physiological manifestations of their disease, particularly chronic pain and fatigue, represent the most immediate barriers to executing prescribed behavioral and pharmacological tasks. Previous structural modeling has demonstrated that high self-efficacy effectively mitigates feelings of clinical helplessness and emotional despair, particularly in populations suffering from severe chronic pain (Mohammadi et al., 2021). This buffering effect is crucial because the enduring belief in one's ability to maintain functional independence despite experiencing debilitating symptoms fundamentally alters a patient's psychosocial adjustment and reduces maladaptive pain catastrophizing (Barzegari Sultan Ahmadi, 2021). Furthermore, studies examining the relationship between psychosocial vulnerabilities and patient-reported functional disability confirm that the degree of symptom-management self-efficacy a patient possesses heavily dictates their functional outcomes (Varela & Van Asselt, 2022). Even when controlling for diverse clinical histories and baseline demographics, self-efficacy remains the predominant determinant of independence (Terzaki et al., 2023). Therefore, when a woman in our cohort feels confident in her ability to control acute symptom flare-ups, she is significantly more likely to adhere to her overarching health regimen, as her psychological capital acts as a shield against disease-related distress. This is further supported by evidence showing that psychological interventions fostering self-compassion and future self-identification inherently rely on parallel enhancements in disease-management self-efficacy to effectively reduce symptom disability (Mistretta et al., 2023).

Following symptom control, the health literacy domain concerning the ability to understand health information was identified as the second most critical predictor. Complex regimens require the continuous cognitive processing of intricate pharmacological schedules, nuanced dietary restrictions, and specific lifestyle modifications. If foundational comprehension is lacking, adherence becomes functionally impossible, regardless of patient motivation. This finding heavily corroborates recent empirical research demonstrating the profound impact of health literacy on physical and psychological health outcomes, often acting through complex pathways that influence self-care behaviors (Lu et al., 2023). Low health literacy directly correlates with an increased symptom burden, which subsequently derails adherence (Yan et al., 2025). Furthermore, in an increasingly digital healthcare landscape, electronic health literacy dictates a patient's ability to seamlessly navigate patient portals and discern reliable medical information, making the comprehension of health data a paramount survival skill for chronic disease self-management (Osokpo, 2025). The inability to understand medical rationale also breeds skepticism; for instance, lower health literacy is independently associated with fatalistic illness beliefs and deep-seated doubts regarding the necessity of daily maintenance medications (Kale et al., 2015). While systemic interventions designed to improve health literacy in populations with complex multi-systemic conditions often yield variable results, our findings emphasize that tailored, context-specific educational strategies focusing explicitly on comprehension are urgently required (Campbell et al., 2022).

The third and fourth most influential predictive features—self-efficacy in communicating with physicians and the health literacy domain of actively engaging with healthcare providers—underscore the indispensable nature of the patient-provider dynamic. Adherence is not a solitary endeavor but a collaborative clinical partnership. Women who possess the confidence to voice their concerns, ask clarifying questions, and actively participate in shared decision-making are significantly more likely to adhere to their agreed-upon regimens. This reflects findings from qualitative investigations showing that patient and professional perspectives on lifestyle modifications heavily rely on the patient's underlying literacies coupled with the psychological self-efficacy to implement them in collaboration with their care team (Hakami et al., 2018). Furthermore, while external social support is highly beneficial, its positive downstream effects on tangible clinical outcomes and self-management are heavily mediated by the patient's underlying self-efficacy to aggressively manage the multifaceted demands of their illness and communicate effectively with their support network (Chen et al., 2018). This intricate relationship is also evident in elderly populations, where the link between broad personality traits and health literacy is heavily mediated by dynamic family communication structures and disease-specific self-efficacy (Zhang et al., 2024). It is crucial to

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recognize that these communication dynamics are often shaped by broader cultural backgrounds, which influence how patients interpret medical advice and navigate complex healthcare systems (Shaw et al., 2008).

Interestingly, our Random Forest model revealed that static sociodemographic factors, including age, duration of illness, educational attainment, and monthly household income, held substantially less predictive weight compared to the modifiable psychological and cognitive constructs. This suggests that while systemic inequities exist, robust health literacy and high self-efficacy can effectively buffer against the traditional barriers associated with lower socioeconomic status and advanced age. This is a highly optimistic finding for clinical practice, as it indicates that adherence is a malleable behavior rather than a fixed demographic destiny. The capacity to maintain a health-promoting lifestyle, even in the face of significant environmental and societal disruptions, demands psychological resilience that can be actively cultivated (Suksatan et al., 2022). Interventions such as targeted motivational interviewing have proven critical in shaping lifestyle choices and long-term adherence behaviors by building this exact type of psychological capital, irrespective of the patient's baseline demographic profile (HosseiniTavan et al., 2023). Furthermore, integrative interventions that combine clinical education with mind-body practices are highly successful because they induce measurable, positive neurocognitive changes in self-efficacy and coping skills, overriding historical demographic disadvantages (Marshall et al., 2022). Ultimately, fostering this self-efficacy acts as an independent predictor of overall psychological well-being and can even serve as a psychological buffer against severe existential distress and death anxiety in advanced chronic disease states (Chen, 2023) (Güçlü & Akça, 2024). The intergenerational reverberations of these optimized cognitive frameworks are also profound, as improved health literacy and self-efficacy in adult women undoubtedly cascade to positively impact the health outcomes and developmental trajectories of their dependents (Zaidman et al., 2023). Diminished health literacy is significantly associated with higher reported levels of distress, making the targeted improvement of these cognitive skills a clinical imperative for pain and disease management (Miller-Matero, 2024).

5. Conclusion

In conclusion, this study validates the application of advanced machine learning algorithms to disentangle the complex behavioral drivers of regimen adherence among women with chronic illnesses. By utilizing a Random Forest approach, we determined that adherence is overwhelmingly driven by modifiable psychological and cognitive assets, specifically a patient's self-efficacy in controlling physiological symptoms and their functional health literacy regarding the comprehension of medical information. The patient's confidence in communicating with healthcare providers and actively engaging in the clinical process also emerged as critical determinants, significantly outweighing traditional sociodemographic factors such as age, income, and formal education levels. These findings pivot the paradigm of chronic disease management away from a rigid focus on demographic risk factors toward a highly empowering, patient-centered model. It firmly establishes that when women are equipped with clear, understandable health information and are psychologically empowered to manage their symptoms and advocate for themselves, they can achieve high levels of adherence to even the most demanding and complex therapeutic regimens.

6. Limitations and Suggestions

Despite the robust predictive accuracy of the models utilized, this study is subject to several methodological limitations that must be acknowledged. Primarily, the cross-sectional predictive design precludes the establishment of definitive temporal or causal relationships between health literacy, self-efficacy, and regimen adherence. While the Random Forest model is highly adept at mapping interactions, adherence behavior is inherently dynamic and may fluctuate over the prolonged course of a chronic illness, a phenomenon this static snapshot cannot capture. Furthermore, the reliance on self-reported psychometric instruments for data collection introduces the potential for recall bias and social desirability bias, where participants may unconsciously inflate their adherence levels or confidence scores to align with perceived clinical expectations. Finally, the purposive sampling of female patients from specific urban and peri-urban referral hospitals in Indonesia may limit the broad generalizability of these findings to rural populations, different genders, or diverse global cultural contexts with vastly different healthcare infrastructures.

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Future research initiatives should prioritize longitudinal cohort studies to track the natural trajectories of health literacy, self-efficacy, and adherence over extended periods, thereby clarifying the causal directionality of these complex relationships. Methodologically, subsequent studies could expand upon the current computational framework by integrating deep learning models or neural networks, and by incorporating objective, biometric measures of adherence, such as electronic pillbox monitoring, pharmacy refill records, or physiological biomarkers, to triangulate and validate self-reported data. There is also a critical need for rigorous randomized controlled trials designed to empirically test the efficacy of targeted, culturally tailored interventions that simultaneously build both symptom-management self-efficacy and functional health literacy. Exploring the specific intergenerational impact of maternal health literacy and self-efficacy on family health dynamics utilizing similar machine learning approaches represents another highly promising avenue for future behavioral health research.

The findings from this predictive modeling present immediate, actionable directives for clinical practice and healthcare policy. Healthcare providers must recognize that simply handing a patient a prescription and a standardized informational pamphlet is fundamentally insufficient for managing complex chronic diseases. Clinical consultations must be intentionally redesigned to actively cultivate a patient's confidence in symptom management, prioritizing collaborative problem-solving for expected physiological side effects or disease flare-ups. Practitioners should routinely employ the teach-back method to verify functional comprehension, ensuring that medical communication is entirely devoid of confusing jargon. Furthermore, health systems should invest in comprehensive, multidisciplinary support programs that coach women on effective communication strategies, empowering them to engage as equal partners in their medical care. By systematically shifting clinical resources to bolster these specific psychological and cognitive skills, healthcare systems can significantly improve adherence rates, reduce preventable hospitalizations, and profoundly enhance the quality of life for women living with chronic illnesses.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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