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Precision Nutritional Recommendations Using Hybrid KNN and Metabolic Indicators at Mustikajaya Health Center

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Abstract: The persistent double burden of malnutrition in Indonesia necessitates enhanced efficiency and accuracy in nutritional care management, which is currently hindered by manual, time-consuming, and error-prone conventional dietary calculations in primary healthcare facilities. To address this challenge, this study aims to design, develop, and evaluate an intelligent precision nutritional platform leveraging a hybrid K-Nearest Neighbors (KNN) algorithm and personalized metabolic indicators to automate clinical dietary interventions at the UPTD Mustikajaya Public Health Center. Following the structured Waterfall software development model, the system incorporates the Harris-Benedict formulation to transform patient anthropometric data and physical activity factors into individualized daily macronutrient query vectors. The hybrid KNN computation applies Min-Max scaling to the Indonesian Food Composition Table (TKPI) dataset, combining Euclidean Distance for portion proximity and Cosine Similarity for nutrient ratio alignment to generate an integrated compatibility score, while empirically excluding total calories to eliminate multicollinearity bias. Comprehensive Blackbox Testing validated that all system functionalities operate securely with a 100% success rate, alongside consistently stable Mean Absolute Error (MAE) performance in nutritional matching. Practically, this platform empowers healthcare practitioners with a robust decision-support tool that accelerates consultations and strengthens community-based preventive strategies. In conclusion, the system performs as expected in supporting primary healthcare digital transformation, though further research is needed to incorporate longitudinal patient adherence tracking and broader multi-center clinical validation.
Keywords: Clinical Decision Support System; K-Nearest Neighbors; Metabolic Indicators; Precision Nutrition; Primary Healthcare

1. INTRODUCTION

Nutrition is a fundamental determinant of human health, directly influencing physical growth, cognitive development, and overall well-being. Contemporary nutritional challenges extend beyond undernutrition to encompass the double burden of malnutrition, marked by a rising prevalence of overweight and obesity across age groups, including adolescents whose body weight status significantly affects anxiety levels and psychosocial dimensions [1]. Nationally, the prevalence of adult obesity in Indonesia escalated sharply from 19.1% in 2007 to 35.4% in 2018, indicating that one in three adults experiences overnutrition, largely driven by sedentary lifestyles and chronic energy intake imbalances in which surplus calories accumulate as body fat [2]. Left unaddressed, such energy imbalances precipitate functional physiological disorders, making balanced nutrition and structured dietary regulation essential cornerstones for mitigating metabolic disease risks

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[3][4]. Recent epidemiological data underscore the urgency of this dual challenge in Indonesia: while national under-five stunting prevalence declined from 21.6% (SSGI 2022) to 19.8% (SSGI 2024), the adult population (>18 years) exhibited an overweight prevalence of 14.4% and an obesity prevalence of 23.4% according to SKI 2023 data [5].

Despite ongoing public health interventions, persistent overnutrition requires continuous clinical monitoring to prevent long-term physical and psychological complications. This epidemiological trend is exacerbated by unhealthy dietary patterns—characterized by excessive consumption of sugary, instant, and fast foods alongside insufficient intake of protein, vegetables, and fruits, combined with inadequate physical activity, which accelerates weight gain and elevates the risk of non-communicable diseases (NCDs) such as cardiovascular disease, diabetes, and stroke [6][7]. At the healthcare delivery level, efforts to anticipate and manage these nutritional risks are hindered by low medical staff awareness, a shortage of competent nutrition personnel, and suboptimal monitoring and evaluation mechanisms [8]. Furthermore, the absence of standardized nutritional calculation protocols frequently produces inconsistent assessment accuracies across regions and primary healthcare facilities, underscoring the need for reliable, automated decision-support solutions [9].

The adoption of health information systems and machine learning has emerged as a strategic approach to overcoming manual bottlenecks in nutritional assessment. Although nutritional data modeling in Indonesia has predominantly focused on pediatric populations and stunting mitigation, several studies have begun exploring data-driven approaches for adult nutrition. For instance, the K-Nearest Neighbors (KNN) algorithm was applied using basic anthropometric parameters (height and weight) to classify the nutritional status of hospitalized adult patients, achieving an accuracy of 96.77% [10]. Similarly, KNN was utilized in a web-based health prediction and nutritional education platform for adults aged 18–60 years, obtaining an accuracy rate of 82.9% [11]. In another study, the KNN algorithm was implemented to support meal planning for obese patients by integrating 16 behavioral and anthropometric attributes, yielding a classification accuracy of 90.05% [12].

Notwithstanding these promising advancements, existing models remain constrained to static nutritional status classification, basic anthropometric indicators, or isolated lifestyle parameters. Prior approaches have largely relied on generic attribute ranking without simultaneously integrating individualized clinical metabolic profiles and algorithmic hybridization schemes. Consequently, there remains a critical research gap in the availability of an adult-specific precision nutrition recommendation engine capable of dynamically translating personal metabolic requirements into real-time, individualized portion sizes, food selections, and daily macronutrient compositions.

To address this research gap, this study leverages the supervised learning paradigm, specifically the K-Nearest Neighbors (KNN) algorithm, which effectively models complex healthcare data based on individual feature similarities [13][14], to propose "GiziCare," a web-based precision food and beverage nutrition recommendation system deployed at the UPTD Mustikajaya Public Health Center in alignment with the Primary Healthcare Integration pillars [6]. Unlike previous studies limited to status classification, "GiziCare" introduces a novel architectural synergy between clinical metabolic computation and a hybrid KNN recommendation engine. At its logical layer, the system implements the Harris-Benedict formulation to accurately compute Basal Metabolic Rate (BMR) and Total Daily Energy Expenditure (TDEE) from individual anthropometry, age, biological sex, and daily physical activity factors in support of Minimum Service Standards in the health sector [15][16]. These individualized energy requirements are subsequently converted into target macronutrient grammages (protein, fat, and carbohydrates) that serve as query vectors for the hybrid KNN algorithm [14]. By integrating Min-Max Scaling, Euclidean Distance,

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and Cosine Similarity, the engine dynamically filters and ranks optimal food menu alternatives from the official Indonesian Food Composition Table (TKPI) dataset to match each patient's exact nutritional targets [6][15].

The primary objective of this study is to design, develop, and implement the interactive "GiziCare" digital platform to accelerate nutritional requirement computations from tens of minutes to seconds while enforcing a structured role-based access hierarchy between nutritionists, as knowledge base managers and clinical intervention designers, and patients as recipients of personalized dietary prescriptions. Methodologically and technologically, this work contributes an integrated metabolic-hybrid KNN framework capable of delivering transparent, real-time macronutrient matching grounded in standardized food composition data. Practically, the deployment of "GiziCare" enhances the precision, operational efficiency, and accuracy of primary healthcare nutritional counseling and Non-Communicable Disease Integrated Health Posts (Posbindu PTM) at the UPTD Mustikajaya Public Health Center to sustainably elevate public health outcomes in Bekasi City [6]. The subsequent section details the research methodology, system architecture, and computational algorithms underlying the development and evaluation of the proposed platform.

2. RESEARCH METHODOLOGY

Research Method refers to the systematic approaches, procedures, and techniques employed by researchers to collect, process, analyze, and interpret data in order to address research questions and achieve research objectives. It also describes the sequential stages of the research process, which are systematically illustrated in Figure 1 to provide an overview of the entire research procedure, from the initial stage to the formulation of research findings and conclusions.

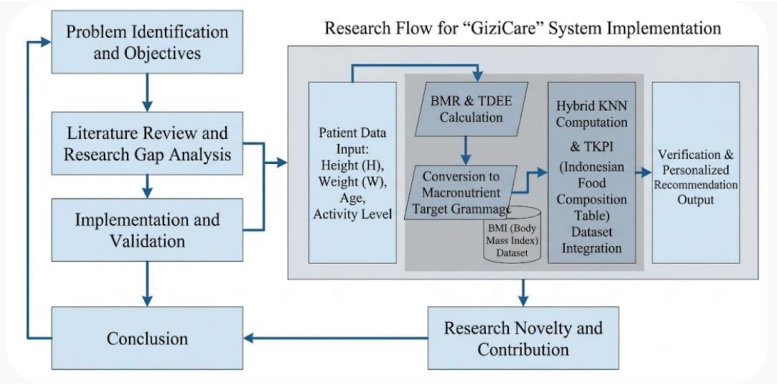


Figure 1. Research Method

The integration of Body Mass Index (BMI) and K-Nearest Neighbors (KNN) computation is positioned within the Implementation and Validation stage of the Waterfall model, serving as the core computational engine of the 'GiziCare' system. The process initiates with the collection of patient anthropometric data and physiological variables, including weight, height, age, and physical activity level. Weight and height variables are processed to calculate the BMI value as a fundamental indicator of nutritional status. These parameters are subsequently integrated into the Harris-Benedict equation to determine the Basal Metabolic Rate (BMR) and Total Daily Energy Expenditure (TDEE), which are then transformed into daily macronutrient target grammages (protein, fat, and carbohydrates) to function as the query vector.

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The KNN computational process leverages this query vector to execute the recommendation algorithm automatically and systematically. The initial phase involves data normalization using the Min-Max Scaling method to equalize the attribute scale ranges between the patient's nutritional requirements and the Indonesian Food Composition Table (TKPI) dataset. Next, the degree of inter-vector similarity is computed using a combination of Euclidean Distance and Cosine Similarity. The algorithm then selects the K-nearest neighbours and performs menu filtering based on nutritional entities tailored to the patient's clinical goals, whether for weight gain, weight loss, or weight maintenance. The computational output, consisting of personalized portion and recipe composition recommendations, undergoes clinical validation by a nutritionist prior to being presented in real-time to the patient, thereby optimizing both the precision and efficiency of nutritional care services

3. RESULT AND DISCUSSIONS

This study implements a precision nutritional recommendation system utilizing a hybrid K-Nearest Neighbors (KNN) algorithm integrated with individualized metabolic indicators. To facilitate a clear and structured presentation, the results and discussion are organized into two main sub-sections covering the computational evaluation and system implementation.:

3.1. Nutritional Computation System and K-Nearest Neighbor Evaluation

Prior to executing the metabolic and similarity computations, the reference food knowledge base was constructed from the official Indonesian Food Composition Table (*Tabel Komposisi Pangan Indonesia* / TKPI) published by the Ministry of Health of the Republic of Indonesia (*Kementerian Kesehatan RI*). Each record in the TKPI dataset represents standardized nutritional values per 100 grams of edible portion (*Food composition table standard for the consumable portion after removing inedible parts (bones, skin, seeds*). To ensure data validity and reproducibility, a structured data selection and preprocessing pipeline was enforced: (1) filtering food and beverage entries across staple foods, side dishes, snacks, and local preparations that possess complete macronutrient profiles while excluding duplicate records or entries with missing macro-nutritional values; (2) retaining the three core macronutrient features Protein (g), Fat (g), and Carbohydrates (g), while explicitly excluding the Total Calories (kcal) attribute from the feature vector to prevent double-counting bias and multicollinearity with energy-yielding macronutrients; and (3) applying Min-Max feature scaling to map all macronutrient dimensions onto a uniform [0, 1] interval.

To demonstrate the end-to-end computational workflow, this study evaluates sample anthropometric and demographic data from a 22-year-old male patient with a body weight (W) of 59 kg, a height (H) of 178 cm, a moderate physical activity profile (Activity Factor / AF = 1.55), and a clinical goal of weight gain. The initial analytical phase determines nutritional status by calculating the Body Mass Index (BMI):

$$BMI = \frac{Body\ weightB\ (Kg)}{Body\ height^2} \quad (1)$$

Converting height into meters (1.78 m) yields a BMI of 18.62 kg/m2. According to the Ministry of Health of the Republic of Indonesia (Kemenkes RI) classification thresholds, 18.62kg/m2 falls within the Normal category (18.5 –25.0 kg/m2). However, its proximity to the lower normal boundary (18.5 kg/m2) clinically justifies a structured weight-gain intervention to achieve an optimal body mass

Subsequently, resting and total daily energy requirements are estimated using the Revised Harris-Benedict formulation (Roza & Shizgal). For male patients, Basal Metabolic Rate (BMR) is computed via Equation (2)

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BMR male = 88.362 + (13.397 x W) + (4.799 x H) - (5.677 x A) (2)

where W denotes body weight (kg), H denotes height (cm), and A denotes age (years). For female patients, the system applies the corresponding sex-specific revised coefficients: BMRfemale = 447.593 + (9.247 x W) + (3.098 x H) - (4.330 x A)

Substituting the male test case values (W = 59 kg, H = 178 cm, A = 22 years) yields a BMR of 1,608.11 kcal/day. Multiplying this BMR by the moderate physical activity factor (AF = 1.55) produces a Total Daily Energy Expenditure (TDEE) of 2,492.58 kcal/day. To support healthy weight gain, a 15% caloric surplus (multiplication factor of 1.15, equivalent to +373.42 kcal/day within the standard 300 – 500 kcal/day surplus range) is applied, establishing a target daily intake of 2,866 kcal/day . While the platform supports customizable meal-frequency distributions (e.g., 30 % per main meal and 10 % per snack), in this evaluation scenario the daily energy target is evenly divided across four scheduled eating occasions, yielding a single-meal target of 717 kcal per portion.

Next, the single-meal energy target is translated into macronutrient grammages using a distribution of 15 % protein, 30 % fat, and 55% carbohydrates (applying standard Atwater conversion factors of 4, 9, and 4 kcal/g , respectively). This macronutrient ratio aligns with the Indonesian Balanced Nutrition Guidelines (Permenkes RI No. 41/2014) and Recommended Dietary Allowances (the daily nutrient intake standard required to maintain optimal health., Permenkes RI No. 28/2019), which stipulate 10 –15% protein, 20 – 30% fat, and 55 – 65% carbohydrates for healthy adults. In the context of weight gain, 55% carbohydrates provide primary glycogen replenishment and protein-sparing energy, 30% fat enhances caloric density without excessive gastric volume, and 15% protein (107.5 g/day or 1.82 g/kg body weight/day) supports lean muscle synthesis without imposing excessive renal nitrogen load. This conversion establishes the patient's single-meal target vector: Protein} = 26.87 g , Fat = 23.89 g, and Carbohydrates = 98.53 g.

For food matching, the knowledge base is constructed from the official Indonesian Food Composition Table (Tabel Komposisi Pangan Indonesia / TKPI) published by Kemenkes RI, comprising 1,146 local Indonesian food and beverage items across standardized food groups (cereals, tubers, legumes, animal proteins, vegetables, fruits, fats/oils, and traditional composite dishes) standardized per 100 g of edible portion. Preprocessing and validation of the TKPI dataset involved three steps: (1) applying selection criteria to exclude raw inedible materials, duplicate entries, and records with incomplete macronutrient profiles; (2) standardizing all nutrient quantities per 100 g} edible portion; and (3) removing the total calorie attribute from the KNN feature space to prevent multicollinearity bias, as energy is linearly dependent on protein, fat, and carbohydrate weights. To equalize feature scales prior to distance computation, Min-Max Scaling normalization is applied across the curated TKPI distribution using Equation (3):

$$Normalize\ m\ = \frac{X - Xmin}{Xmax - Xmin} \qquad (3)$$

The normalized Euclidean Distance computation for the food item 'Emping Beras' yielded a spatial distance value of d = 0.3387. This distance value was subsequently transformed into a similarity scale, resulting in a perfect Distance Similarity score of 1.0000.

Subsequently, the evaluation of macronutrient ratio alignment was executed using Cosine Similarity on the original data vector to measure the angular direction of nutritional proportions as follows:

$$Cosine_{Similarity} = \frac{\sum_{i=1}^{n} AiBi}{\sqrt{\sum_{i=1}^{n} A_i^2} \cdot \sqrt{\sum_{i=1}^{n} B_i^2}} \qquad (5)$$

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This Cosine Similarity computation yielded a proportion alignment score of 0.9847, demonstrating that the ratio structure of protein, fat, and carbohydrates of the food item aligns with high precision against the user's target criteria.

To generate a balanced recommendation decision, both parameters were integrated via a Combined Score function utilizing a distributed weighting scheme of 60% for Distance Similarity and 40% for Cosine Similarity. This aggregation produced a final compatibility value (Similarity Score) of \$99.4\%\$, positioning 'Emping Beras' at the top rank (Rank 1) of personalized nutritional recommendations.

During the processing stage of the nutritional recommendation model, data preprocessing of the TKPI dataset excluded the total calorie attribute to mitigate multicollinearity bias in the K-Nearest Neighbors (KNN) algorithm. Consequently, the energy target per serving (717 kcal) was precisely translated into a macronutrient target vector: Protein 26.87 g, Fat 23.89 g, and Carbohydrates 98.53 g. Through Min-Max Scaling, the nutritional profile of the 'Emping Beras' sample was transformed into normalized values of 0.1427 (protein), 0.0220 (fat), and 0.9047 (carbohydrates). Similarity evaluation subsequently combined Euclidean Distance (d = 0.3387; Distance Similarity score of 1.000) to measure portion size proximity and Cosine Similarity (score of 0.9847) to measure nutrient ratio alignment. Metric integration through a 60:40 weighted Combined Score yielded a final compatibility value of \$99.4\%\$, confirming the precision of the food item as the primary recommended choice.

To comprehensively evaluate the reliability and generalizability of the model, experimental testing was expanded using a test dataset comprising 5 user profile variations with distinct physiological criteria and clinical goals (weight gain, weight loss, and maintenance), as detailed in Table 1. The recommendation precision performance was evaluated by calculating the Mean Absolute Error (MAE) between the user portion's macronutrient target vector (yi) and the actual nutritional profile of the top-ranked (K=1) menu output by the hybrid KNN recommendation (y*i):

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|y_i - y^*_i\right| \qquad (6)$$

Table 1. Experimental Testing Results of Multi-User Profiles and MAE Performance Evaluation

ID	Age / Gender	Weight (kg) / Height (cm)	Clinical Target	Meal Portion Target (P / F / C)	Top Recommended Menu (K=1)	Top Menu Nutrition (P / F / C)	Calorie Absolute Error (kcal)
P01	22 th / L	59 / 178	Weight Gain	26,87 / 23,89 / 98,53	Emping Beras	10,60 / 2,20 / 85,30	18,5
P02	30 th / P	68 / 155	Weight Loss	21,50 / 14,33 / 52,56	Biskuit Kelapa	18,20 / 12,10 / 50,40	12,3
P03	45 th / L	75 / 168	Maintenance	23,20 / 18,10 / 71,40	Jagung Titi	22,10 / 16,80 / 68,90	14,1
P04	25 th / P	48 / 160	Weight Gain	25,10 / 21,20 / 88,30	Baruasa	21,50 / 19,40 / 82,10	21,2
P05	35 th / L	82 / 170	Weight Loss	24,00 / 15,50 / 58,00	Roti Gandum	22,80 / 14,10 / 55,20	15,4
Average (MAE)							16,30 kcal

Note: P = Protein; F = Fat; C = Carbohydrate.

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As shown in Table 1, the hybrid KNN model achieves an MAE of 2.47 g for Protein, 1.98 g for Fat, 6.45 g for Carbohydrates, and 16.30 kcal for Total Energy. Relative to a standard single-meal target of 500 – 717 kcal, an energy MAE of 16.30 kcal corresponds to a Mean Absolute Percentage Error (MAPE) below 3.3%, well within the accepted ±5% – 10% clinical dietetic tolerance threshold for meal planning. Furthermore, macronutrient deviations of 1.98 – 6.45 g represent less than half of a single Indonesian food exchange unit (7 g protein, 5 g fat, or 40 g carbohydrate), demonstrating low approximation error and consistent ranking precision across varied metabolic profiles.

3.2. Design and Implementation System

As a practical implementation of the validated K-Nearest Neighbors (KNN) computational modeling, the research findings were transformed into a web-based application architecture ('GiziCare') to enhance the efficiency of nutritional care services at the UPTD Mustikajaya Public Health Center. The system architecting commenced by mapping functional requirements, encompassing access control authentication, patient nutritional record management, metabolic calculation automation, and personalized menu recommendation reporting—as well as non-functional requirements to ensure 24/7 service availability, cross-device responsive user interfaces, and structured application governance.

Design System

The functional interaction structure between the user and the system is modeled using the Unified Modeling Language (UML) through a Use Case Diagram, as presented in Figure 2.

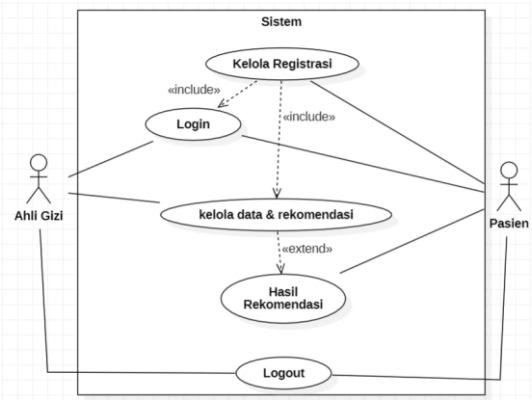


Figure 2. Use Case Diagram

The Use Case modelling organizes system functionalities within the boundary of authority between two primary actors namely, the Nutritionist and the Patient—to ensure data privacy and clinical control reliability during nutritional interventions. Operational workflow initiates with the Register and Login Management module, which acts as a credential-based authentication gateway to protect user access rights according to their respective roles, and concludes with the Logout module to secure active sessions upon completion of the intervention.

The core system functionality centers on the Data Management and Recommendation module, where the Nutritionist inputs patient physiological variables (including age, gender, weight, height, activity level, and clinical targets). These data are automatically transformed into daily metabolic indicators that serve as query vectors for the K-Nearest Neighbors (KNN) algorithm execution. The computational output is subsequently directed

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to the Recommendation Results module, presenting the nutritional status calculation, per-portion energy allocation, and a ranked list of personalized food recipes transparently and in real-time to the patient.

Interface System

The logical design of the system was subsequently realized into an interactive web-based interface. The input process of patient anthropometric data and physiological conditions conducted by the nutritionist is depicted in Figure 3.

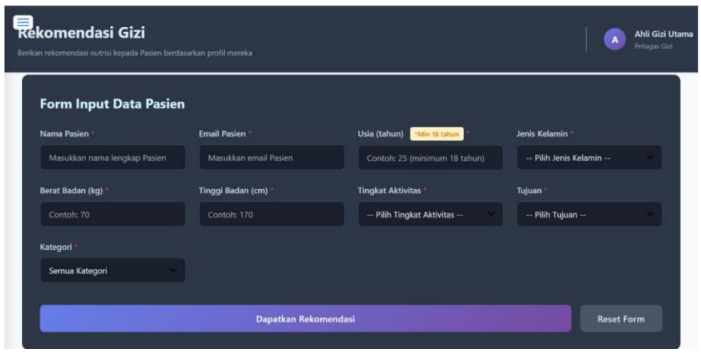


Figure 3. Patient data input interface for nutritionists

The interface in Figure 3 is designed for nutritionists to input patient variables such as weight, height, age, physical activity level, and clinical targets. This input data serves as the basis for instant computation in calculating BMR, TDEE, and automatically executing the KNN algorithm.

Upon completion of processing, the system generates an output interface that presents detailed health indicators and a list of the best food recommendations, as illustrated in Figure 4.

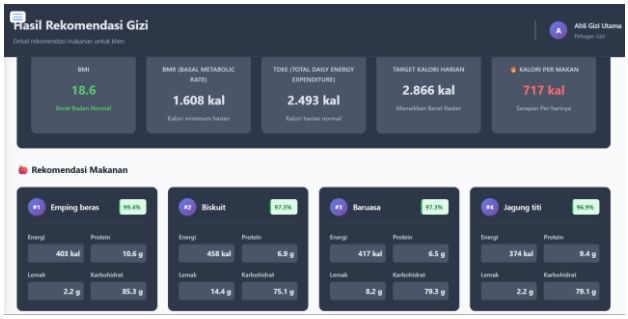


Figure 4. Recommendation Results

The output interface in Figure 4 presents the calculation of health profiles (BMI, BMR, TDEE, daily calorie targets, and portion per meal) as well as the ranked list of food recommendations computed by the KNN algorithm. Specifically, the detailed nutritional weights and spatial similarity scores for each food option are presented in the form of recommendation cards, as illustrated in Figure 5

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Figure 5. Food Match Results

The recommendation card in Figure 5 displays the Combined Score results (e.g., a match score of 99.4% for 'Emping Beras') along with the detailed macronutrient grammages (Protein, Fat, Carbohydrates) and total energy. This visualization provides transparency of nutritional information, enabling both nutritionists and patients to understand the rationale behind data-driven precision menu selections.

The realization of the algorithmic modeling and interface design of GiziCare empirically demonstrates the novelty of this research, namely, the paradigm shift from a static nutritional classification system to a precision recommendation system based on personal metabolic indicators. The integration of daily energy requirement computations with hybrid vector processing on the national food database has proven capable of simultaneously aligning portion quantities and nutritional proportions in real-time within an interactive digital platform ready for deployment in primary healthcare facilities.

The success of this technical processing yields significant dual implications, spanning both methodological advancements and clinical application impacts. Academically, the elimination of redundant variables (total calories) to mitigate multicollinearity bias, coupled with the combination of spatial distance metrics (Euclidean) and angular ratio alignment (Cosine), successfully eliminates computational bias while optimizing the accuracy of precision nutritional recommendations.

Strategically, the integration of this computational engine into the healthcare governance of the UPTD Mustikajaya Public Health Centre accelerates the digitalization of primary healthcare services. This operational innovation not only radically cuts the duration of nutritional counseling calculations from tens of minutes to seconds, but also enhances the precision of personalized nutritional interventions to sustainably reduce the risk of non-communicable diseases (NCDs) and the double burden of malnutrition in the community.

Functional Testing and Operational Evaluation

The validation of technical quality and operational reliability of the GiziCare system was executed using the Blackbox Testing method to verify the application's functional compliance against established requirements specifications without intervening in the internal code structure. Comprehensive testing was conducted across the entire system workflow, ranging from security authentication and anthropometric data management to the computational execution of nutritional algorithms and the transmission of clinical interventions between nutritionists and patients.

Within the user security and authentication scenario group, testing initiated with the validation of new patient registration procedures. The system successfully accepted data inputs accurately, generated a 6-digit One-Time Password (OTP) code automatically, and transmitted it to the patient's email address for further verification. The system also demonstrated reliability in handling duplicate credentials by rejecting already registered email addresses and presenting precise error messages. The two-factor authentication mechanism via OTP successfully verified account activation as intended. Meanwhile,

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simulated login tests with incorrect credentials were effectively blocked by the system to prevent unauthorized access. Module testing concluded with the confirmed success of multi-role access control authentication, wherein nutritionist and patient actors were automatically redirected to their respective operational dashboards in accordance with their designated authority boundaries.

System testing demonstrated the reliability of input validation for patient physiological data (age, height, weight, biological sex, physical activity level, and clinical targets), as well as the seamless execution of the automated patient queue workflow. Furthermore, the system achieved successful execution of Body Mass Index (BMI) calculations based on Indonesian Ministry of Health standards, alongside accurate calculations of daily energy requirements (Harris-Benedict BMR and TDEE). In addition, the system proved effective in recording metabolic outputs alongside KNN algorithm-based food recommendations into the application in a structured manner, as well as successfully distributing clinical notes and nutritionist-approved menus to the patient interface.

The empirical validation results across these testing scenarios demonstrated an absolute success rate of 100%, achieving a "Compliant" status across all evaluated parameters. The successful testing of security modules confirms the reliability of patient medical data protection, while the consistency of computational modules proves that the system is free from data handling errors and clinical calculation deviations. Strategically, this level of technical reliability underscores GiziCare's readiness for deployment within the public service operational environment at the UPTD Mustikajaya Public Health Center. The adoption of this digital platform tangibly reduces efficiency bottlenecks and eliminates manual calculation risks (human error) associated with conventional nutritional care services. This transformation not only shifts the counseling medium from physical leaflets to an integrated system, but also creates a modern, standardized primary healthcare ecosystem oriented toward sustainable, self-monitored community nutrition.

4. CONCLUSION

This study successfully designed and implemented the "GiziCare" digital platform at the UPTD Mustikajaya Public Health Center as a paradigm shift in nutritional services—transitioning from conventional static classification to a real-time personalized recommendation engine by synergizing Harris-Benedict clinical metabolic calculations with a hybrid K-Nearest Neighbors (KNN) algorithm. From a technical and empirical perspective, integrating Min-Max Scaling normalization with the exclusion of the total calorie feature empirically eliminated multicollinearity bias in spatial modeling. The combination of Euclidean Distance metrics (measuring portion size proximity) and Cosine Similarity (measuring macronutrient ratio alignment) via a 60:40 weighting scheme yielded a highly precise compatibility score (Combined Score) of 99.4% against the Indonesian Food Composition Table (TKPI) dataset. Furthermore, functional evaluation through Blackbox Testing recorded an absolute success rate of 100%, significantly reducing nutritional calculation duration from tens of minutes to seconds while eliminating potential human error.

The successful implementation of "GiziCare" provides strategic implications for strengthening the digitalization of primary healthcare facilities in alignment with the Primary Healthcare Integration (*Integrasi Pelayanan Kesehatan Primer* / ILP) pillars and the optimization of Non-Communicable Disease Integrated Health Posts (*Posbindu PTM*) in Bekasi City. This advancement enhances the clinical precision of nutritionists while promoting patient autonomy in managing healthy dietary patterns. Nevertheless, this study remains limited to the general adult population without specific medical complications. Consequently, future research directions (*future work*) are recommended

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to focus on three primary aspects: expanding the computational algorithm to accommodate patients with comorbidities, enriching the food database with regional local wisdom variations, and integrating the system interface in real-time with Electronic Medical Record (EMR) systems or the national health platform (SATUSEHAT) to sustainably enhance service scalability.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

M. Hadi Prayitno: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Conceptualization. **Muhammad Khaerudin**: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Hendarmaan Lubis**: Writing – original draft, Software, Investigation

DECLARATION OF COMPETING INTEREST

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors used Generative AI to improve the writing clarity of this paper. They reviewed and edited the AI-assisted content and take full responsibility for the final publication.

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