Assessing Obesity Risk in Student : A Fuzzy Logic Approach for Precision Health

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Abstract. Obesity is a significant and increasing global health challenge, impacting individuals and society on multiple fronts. Its prevalence continues to increase and attacks individuals from various age groups, including students at the Polytechnic. The transition from adolescence to adulthood, a period marked by the attainment of higher education, is a critical period in the formation of health behaviors and lifestyle habits. This phase offers an important opportunity to identify and reduce risk factors associated with obesity. Conventional methods for assessing obesity risk, such as Body Mass Index (BMI), although useful, often oversimplify the complex web of factors that contribute to obesity. These methods fail to account for the complex interactions between genetic, environmental, and lifestyle variables, all of which play an important role in the development of obesity. This research applies innovative fuzzy logic in assessing the risk of obesity among students, thereby advancing the field of precision health. Our research seeks to bridge the gap between conventional risk assessment methods and the complex reality of obesity development, by providing insight into effectively identifying and supporting students at risk of obesity. The result of research shows that the system that has been created can identify the level of risk of obesity in students. The obesity risk results for the students were obtained with the respective obesity risk Low = 0.659991319967, Medium obesity risk = 0.340008680033 and High obesity risk = 0.

Keywords: Body Mass Index (BMI), Fuzzy Logic, Health, Obesity,

1. Introduction

Human Resource Development is one of the national development priorities to prepare and improve the quality of the working age population so that they really get opportunities and play a role in making it happen [1]. To realize high quality Human Resources, one way is through development in the health sector. Indonesia is experiencing a burden of health problems, namely that there are still many people who are malnourished, but on the other hand there is excess nutrition [2]. Malnutrition or overnutrition is caused by a lack of balance between nutritional intake and the body's

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nutritional needs. This cannot be separated from the food consumed every day. The problem of under- and over-nutrition in adults (aged 18 years and over) is an important problem, because apart from having a risk of certain diseases, it can also affect work productivity [3].

A diet that is high in carbohydrates, high in fiber, low in fat changes to a new diet that is low in carbohydrates, high in fat, thus shifting the quality of food towards an imbalance [4]. Factors that can cause obesity are food intake, gender and age [5]. From these opinions, it can be concluded that diet is the main center that must be paid attention to. Because diet makes a significant contribution to increasing the risk of obesity, such as what one eats and how many times one eats it [6]. Apart from that, the health status of students is an important thing for parents, society, and the government to pay attention to because it concerns the quality of the nation's next generation [2].

Obesity is a significant and increasing global health challenge, impacting individuals and society on multiple fronts [7]. Its prevalence continues to increase and attacks individuals from various age groups, including students at the Indramayu State Polytechnic (Polindra). The transition from adolescence to adulthood, a period marked by the attainment of higher education, is a critical period in the formation of health behaviors and lifestyle habits [8]. This phase offers an important opportunity to identify and reduce risk factors associated with obesity. Accurately assessing and measuring the level of obesity risk among Polindra students is critical, as this serves as a basis for tailored interventions and promotion of appropriate health strategies.

Conventional methods for assessing obesity risk, such as Body Mass Index (BMI), although useful, often oversimplify the complex web of factors that contribute to obesity. These methods fail to account for the complex interactions between genetic, environmental, and lifestyle variables, all of which play an important role in the development of obesity. Body Mass Index (BMI) is a measurement or screening tool used to determine a person's BMI body composition based on their weight and height, which is then calculated using this method [9]. Obesity tends to dominate the BMI of individuals over 18 years of age. There are 11.7% cases of obesity or overweight in the adult age group and 10% cases of overweight [10].

In response to these limitations, emerging computational techniques, such as fuzzy logic, have emerged as promising tools for achieving a more accurate and nuanced understanding of obesity risk [3]. Fuzzy logic is a mathematical framework capable of dealing with the uncertainty and imprecision inherent in real-world data [11][12]. Its adaptability to complex multifactorial problems positions it as an ideal candidate for modeling the diverse nature of obesity risk [13]. By integrating multiple input variables and measuring their impact on obesity risk levels, fuzzy logic approaches can offer a more comprehensive and personalized assessment of an individual's susceptibility to obesity [14].

This research applies innovative fuzzy logic in assessing the risk of obesity among Polindra students, thereby advancing the field of precision health. Our research seeks to bridge the gap between conventional risk assessment methods and the complex reality of obesity development, by providing insight into effectively identifying and supporting students at risk of obesity.

2. Research Methods

This research uses the waterfall method, where the software development methodology has a linear sequential nature or classic life flow. The system requirements needed in this research are functional requirements where the system created will produce a model capable of calculating how high the risk of obesity is in a student based on several factors, namely the student's daily habits and food intake. This system will produce output in the form of applying the fuzzy logic method to obtain targets from unknown classes. The process of analyzing and collecting system requirements in accordance with system objectives with the required interfaces.

In this study, there were six variables used, namely input variables (BMI (Body Mass Index), gender, parental history of obesity, exercise habits, fiber consumption, fast food consumption) and one output variable, namely obesity risk level.

2.1. Input Variable (BMI)

The BMI variable consists of 3 sets namely thin, normal and fat.

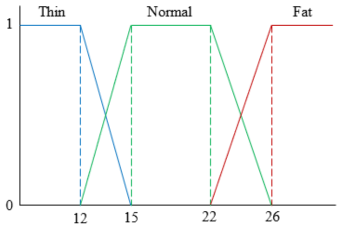

Fig. 1. BMI Associaton Membership Function

$$\mu BMI\_K[x] = \begin{cases} 1; & x \le 12 \\ \dfrac{15 - x}{15 - 12}; & 12 \le x \le 15 \\ 0; & x \ge 15 \end{cases}$$

$$\mu BMI\_N[x] = \begin{cases} 0; & x \le 12 \text{ atau } x \ge 26 \\ \dfrac{x - 12}{15 - 12}; & 12 \le x \le 15 \\ 1; & 15 \le x \le 22 \\ \dfrac{26 - x}{26 - 22}; & 22 \le x \le 26 \end{cases}$$

$$\mu BMI\_G[x] = \begin{cases} 0; & x \le 22 \\ \dfrac{x - 22}{26 - 22}; & 22 \le x \le 26 \\ 1; & x \ge 26 \end{cases}$$

2.2. Input Variable (Gender)

The gender variable consists of 2 fuzzy sets, namely male and female.

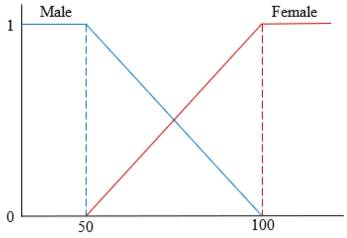

Fig. 2. Gender Fuzzy Set Membership Function

$$\mu Jenis\_Kelamin\_L[x] = \begin{cases} 1; & x \leq 50 \\ \dfrac{100 - x}{100 - 50}; & 50 \leq x \leq 100 \\ 0; & x \geq 100 \end{cases}$$

$$\mu Jenis\_Kelamin\_P[x] = \begin{cases} 0; & x \leq 50 \\ \dfrac{x - 50}{100 - 50}; & 50 \leq x \leq 100 \\ 1; & x \geq 100 \end{cases}$$

2.3. Input Variable (Parental History of Obesity)

The parental obesity history variable consists of 2 fuzzy sets, namely absent and present.

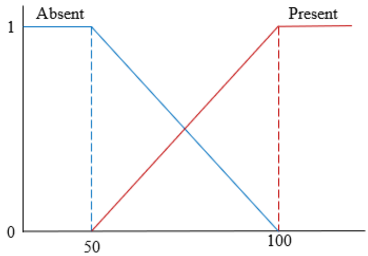

Fig. 3. Function Fuzzy Association Membership Function of Parental Obesity History

$$\mu ROB\_TA[x] = \begin{cases} 1; & x \leq 50 \\ \dfrac{100 - x}{100 - 50}; & 50 \leq x \leq 100 \\ 0; & x \geq 100 \end{cases}$$

$$\mu ROB\_A[x] = \begin{cases} 1; & x \leq 50 \\ \dfrac{x - 50}{100 - 50} & 50 \leq x \leq 100 \\ 0; & x \geq 100 \end{cases}$$

2.4. Input Variables (Exercise Habits)

The exercise habit variable consists of 3 fuzzy sets, namely often, rarely and never.

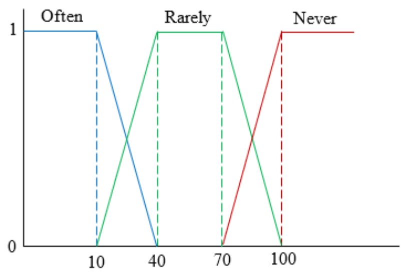

Fig. 4. Membership Function of Fuzzy Sets of Sports Habits

$$\mu Sport\_Habits\_S[x] = \begin{cases} 1; & x \leq 10 \\ \dfrac{40 - x}{40 - 10}; & 10 \leq x \leq 40 \\ 0; & x \geq 40 \end{cases}$$

$$\mu Sport\_Habits\_J[x] = \begin{cases} 0; & x \leq 10 \text{ atau } x \geq 100 \\ \dfrac{x - 10}{40 - 10}; & 10 \leq x \leq 40 \\ 1; & 40 \leq x \leq 70 \\ \dfrac{100 - x}{100 - 70}; & 70 \leq x \leq 100 \end{cases}$$

$$\mu Sport\_Habits\_TP[x] = \begin{cases} 0; & x \leq 70 \\ \dfrac{x - 70}{10 - 70} & 70 \leq x \leq 100 \\ 1; & x \geq 100 \end{cases}$$

2.5. Input Variable (Fiber Consumption)

The fiber consumption variable consists of 3 fuzzy sets, namely a lot, a little and none.

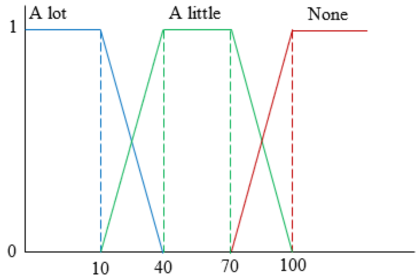

Fig. 5. Fuzzy Set Membership Function Fiber consumption

$$\mu Serat\_B[x] = \begin{cases} 1; & x \le 10 \\ \dfrac{40 - x}{40 - 10}; & 10 \le x \le 40 \\ 0; & x \ge 40 \end{cases}$$

$$\mu Serat\_S[x] = \begin{cases} 0; & x \le 10 \text{ atau } x \ge 100 \\ \dfrac{x - 10}{40 - 10}; & 10 \le x \le 40 \\ 1; & 40 \le x \le 70 \\ \dfrac{100 - x}{100 - 70}; & 70 \le x \le 100 \end{cases}$$

$$\mu Serat\_TA[x] = \begin{cases} 0; & x \le 70 \\ \dfrac{x - 70}{100 - 70} & 70 \le x \le 100 \\ 1; & x \ge 100 \end{cases}$$

2.6. Input Variable (Fast Food Consumption)

The fast food consumption variable consists of 3 fuzzy sets, namely never, rarely and often.

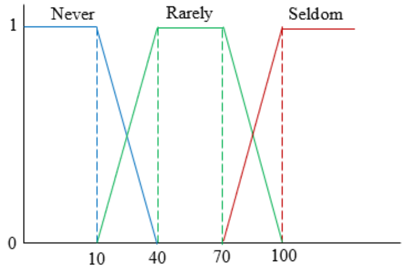

Fig. 6. Fuzzy Set Membership Function Fast Food consumption

$$\mu Fast\ Food\_TP[x] = \begin{cases} 1; & x \le 10 \\ \dfrac{40 - x}{40 - 10}; & 10 \le x \le 40 \\ 0; & x \ge 40 \end{cases}$$

$$\mu Fast\ Food\_J[x] = \begin{cases} 0; & x \le 10 \text{ atau } x \ge 100 \\ \dfrac{x - 10}{40 - 10}; & 10 \le x \le 40 \\ 1; & 40 \le x \le 70 \\ \dfrac{100 - x}{100 - 70}; & x \ge 100 \end{cases}$$

$$\mu Fast\ Food\_S[x] = \begin{cases} 0; & x \le 70 \\ \dfrac{x - 70}{100 - 70} & 70 \le x \le 100 \\ 1; & x \ge 100 \end{cases}$$

2.7. Output Variable (Obesity Risk Level)

The obesity risk level variable consists of 3 fuzzy sets, namely low, medium and high.

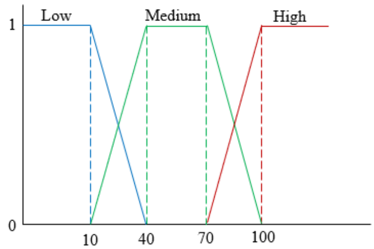

Fig. 7. Function Obesity Risk Level

$$\mu TRO\_R[x] = \begin{cases} 1; & x \leq 10 \\ \dfrac{40 - x}{40 - 10} & 10 \leq x \leq 40 \\ 0; & x \geq 40 \end{cases}$$

$$\mu TRO\_S[x] = \begin{cases} 0; & x \leq 10 \text{ atau } x \geq 100 \\ \dfrac{x - 10}{40 - 10}; & 10 \leq x \leq 40 \\ 1; & 40 \leq x \leq 70 \\ \dfrac{100 - x}{100 - 70}; & 70 \leq x \leq 100 \end{cases}$$

$$\mu tTRO\_T[x] = \begin{cases} 0; & x \leq 70 \\ \dfrac{x - 70}{100 - 70} & 70 \leq x \leq 100 \\ 1; & x \geq 100 \end{cases}$$

3. Result and discussion

The fuzzy stage after defining the variables is determining the rule (inference). In this research, by combining the fuzzy sets Thin, Normal, Fat, Male, Female, None, Existing, Often, Rarely, Never, Many, Little, None, Low, Medium, High from 7 variables, the rule is obtained (rules) as follows:

1. IF BMI is Thin AND Gender is Male AND Parental Obesity History is None AND Exercise Habits are Frequent AND Fiber Consumption is Lots AND Fastfood Consumption is Never THEN Obesity Risk Level is Low.
   α1 = MIN(BMI_K[13.0200260401],Gender_L[100],
   History Parental Obesity_TA[50],
   Exercise Habits_S[55], Consumption
   Fiber_B[55],Fastfood Consumption_TP[55])
   = (0.659991319967,0.1,0,0.0) = 0
   According to the membership function of the set of low obesity risk levels:
   z1 = α1*(40-z)/30 = 40
2. IF BMI is Thin AND Gender is Male AND Parental Obesity History is None AND Exercise Habits are Frequent AND Fiber Consumption is Lots AND Fastfood Consumption is Rare THEN Obesity Risk Level is Low.
   α2 = MIN(BMI_K[13.0200260401],Gender_L[100],
   History Parental Obesity_TA[50], Exercise
   Habits_S[55],Consumption Fiber_B[55], Fastfood
   Consumption_J[55])
   = (0.659991319967,0.1,0,0.1) = 0
   According to the membership function of the set of low obesity risk levels:
   z2 = 40
3. IF BMI is Thin AND Gender is Male AND Parental Obesity History is None AND Exercise Habits are Frequent AND Fiber Consumption is Lots AND Fastfood Consumption is Frequent THEN Obesity Risk Level is Low.
   α3 = MIN(BMI_K[13.0200260401],Gender_L[100],
   History Parental Obesity_TA[50], Exercise

Habits_S[55],Consumption Fiber_B[55],Fastfood Consumption_S[55])
= (0.659991319967,1,0,0,0,0) = 0
According to the membership function of the set of low obesity risk levels:
z3 = 40

4. IF BMI is Thin AND Gender is Male AND Parental Obesity History is None AND Exercise Habits are Frequent AND Fiber Consumption is Little AND Fastfood Consumption is Never THEN Obesity Risk Level is Low.
α4 = MIN(BMI_K[13.0200260401],Gender_L[100], History Parental Obesity_TA[50], Exercise Habits_S[55],Consumption Fiber_S[55],Fastfood Consumption_TP[55])
= (0.659991319967,0,1,0,1,0) = 0
According to the membership function of the set of low obesity risk levels:
z4 = 40
5. If BMI is Thin AND Gender is Male AND Parental History of Obesity is None AND Exercise Habits are Frequent AND Fiber Consumption is Little AND Fastfood Consumption is Rare THEN Obesity Risk Level is Low.
α5 = MIN(BMI_K[13.0200260401],Gender_L[100], History Parental Obesity_TA[50], Exercise Habits_S[55],Consumption Fiber_S[55],Fastfood Consumption_J[55])
= (0.659991319967,0,1,0,1,1) = 0
According to the membership function of the set of low obesity risk levels:
z5 = 40

After obtaining the predicate α and x values (the estimated value of the child's obesity risk level), the next step is to look for the crisp output, the firm Z value. In the Tsukamoto method, to get the crisp output, the centered average defuzzification formula is used:

From the defuzzification process, an obesity risk level value of 23.4641666521 was obtained, which is in the set of Low and Medium Obesity Risk Levels and is between the domains [10 40]. So the results for obesity risk levels can be searched using the obesity risk set membership function formula as below:

$$Z = \frac{\sum \alpha * z}{\sum \alpha}$$

$$Z = \frac{23.4641666521}{1} = 23.4641666521$$

$$\mu_{TRO} RENDAH[23.4641666521] = \frac{40 - 23.4641666521}{40 - 10}$$
$$= 0.551194444929$$

$$\mu_{TRO} SEDANG[23.4641666521] = \frac{23.4641666521 - 10}{40 - 10}$$

$$= 0.448805555071$$

$$\mu_{TRO} TINGGI[23.4641666521] = 0$$

At this stage, the flow of the system being created will be explained. Several processes that will occur in this system are presented with UML diagrams, including use case diagrams, activity diagrams, sequence diagrams and class diagrams.

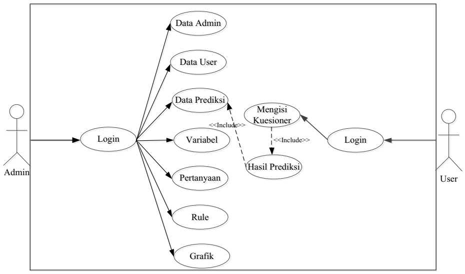

Fig. 8. Usecase Diagram system

This system begins with the user first logging in using the email and password that has been registered in the system. After successfully logging in, the user goes to a fuzzy page which consists of a questionnaire form and prediction results. Users fill out a questionnaire containing 7 questions. Then the user's answers are processed by the system to get a value for the risk level of obesity. After being processed by the system, the user can see the prediction results of the answer in the prediction results menu.

To be able to see the data that has been entered into the fuzzy system, the admin must first log in. After successfully logging in, the admin is directed to the home menu page which consists of admin data, user data, prediction data, variables, questions, rules, graphs, change password and log out. The admin menu contains admin data that has been registered in the system. User data contains user or child data that has been registered in the system. The prediction menu contains the respective membership values, variable membership values, antecedent and z values, defusification and the level of obesity risk for each child. The variable menu contains variable data used in the fuzzy system. The Questions menu contains data on questions asked to users and there are editing tools to change questions. The rules menu contains the rules or regulations used in the child obesity risk level system. The graph menu contains the average prediction from student data that has been entered into the system.

Before entering the admin system, you must log in first by filling in the username and password on the login form that has been registered in the system. After successfully logging in, the system will direct you to the user's main menu, which is a page where the user fills in questions about obesity factors in children such as weight, height, gender, history of parental obesity, exercise habits, fiber consumption and fast-food consumption. Users can also see prediction results after filling out the questionnaire.

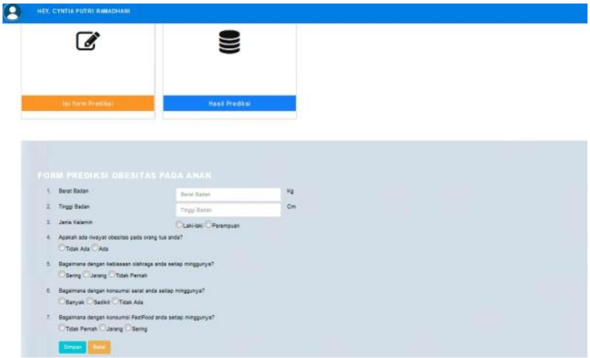

Fig. 9. User's Main menu

While at the admin level, when you successfully log in you will be directed to the Home menu which is the main menu display for admins which consists of admin data, user data, prediction data, variables, questions, rules and graphs. Admins can add, change, delete admin data, change and delete users, and change questions.

Fig. 10. Admin Main menu

After the user fills in the questionnaire, the system will process it to see the user's obesity level according to the answers given by the user. Apart from that, a graph of the obesity results for each user who uses the system is also displayed.

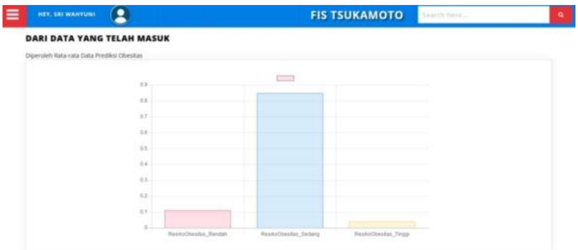

Fig. 11. Grafik menu

Perception or degree of mass membership of each fuzzy variable BMI_Thin = 0.659991319967, BMI_Normal = 0.340008680033, BMI_Fat=0, Gender_Male=0, Gender_Female=1, Parental Obesity History_Present = 0 , Parental Obesity History_Absent = 1 , Frequent Exercise Habits = 0 , Exercise Habits_Rarely = 1 , Exercise Habits_Never = 0 , Consumption of Fiber_A Lot = 0 , Consumption of Fiber_A Little = 1 , Consumption of Fiber_None = 0 , Consumption of Fast Food_Never = 0 , Consumption of Fast Food_Rarely = 1 and Consumption of Fast Food_Frequently = 0 . Then the next stage is the combination of the fuzzy sets into 324 rules, which then obtains the predicate α and z values (the estimated value of the risk of child obesity), then proceeds to the defuzzification stage to obtain the final value of the risk level of child obesity. From this process, the results of the risk of obesity in children were obtained with the respective risk values for obesity_Low = 0.659991319967, risk for obesity_Medium = 0.340008680033 and risk for obesity_High = 0.

From the results obtained, it can be seen that the risk level for obesity for Polindra students is at a low level.

4. Conclusion

Based on the results of the research conducted, it can be concluded that the system that has been created can identify the level of risk of obesity in Polindra students. The application of fuzzy logic in this system is by entering 6 fuzzy input variables which include perception or degree of mass membership of each fuzzy variable BMI_Thin = 0.659991319967, BMI_Normal = 0.340008680033, BMI_Fat=0, Gender_Male=0, Gender_Female=1, History Parental Obesity_Present = 0, Parental Obesity History_None = 1, Frequent Exercise Habits = 0 , Rarely Exercise_Habits = 1, Exercise_Never = 0, Lots of Fiber Consumption = 0, Little_Fiber Consumption = 1 , Absent Fiber Consumption = 0, Fast Food Consumption_Never = 0, Fast Food Consumption_Rarely = 1 and Fast Food Consumption_Frequently = 0. Then combine the fuzzy sets into 324 rules, then obtain the predicate α and z values (the estimated obesity risk value), then proceed to the defuzzification stage to obtain the final obesity risk level value. From this process, the obesity risk results for Polindra students were obtained with the respective obesity risk_Low = 0.659991319967, Medium_obesity risk = 0.340008680033 and High_obesity risk = 0.

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