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MODELING OF DETERMINING THE DEGREE OF OBESITY USING THE FUZZY LOGICAL INFERENCE METHOD

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Abstract. *The article is devoted to computer modeling of the social and medical problem of determining the degree of obesity of body mass. An analysis was conducted, the significance of the solution to the problem was revealed. Using modern mathematical methods based on the theory of fuzzy sets and the method of fuzzy logical deduction, an approach is presented to determining the degree of obesity of body weight. Based on a short review, it was concluded that the body mass index, waist circumference size, degrees of abdominal obesity are recognized as direct factors in measuring the degree of obesity of body weight. Since all three factors are fuzzy parameters, the method of fuzzy logic inference is used to make a decision. The revealed universes of fuzzy variables of obesity of body weight, body mass index, waist circumference size, degrees of abdominal obesity. With the help of vague production rules, the answer options are provided for various situations. Fuzzy logical inference is implemented by the Mamdani method. The constructed model allows to calculate obesity rates for a large number of people in a short period of time objectively and accurately. Due to this feature, the developed approach can be used in population studies when defining specific categories of body weight as a health problem. The accumulated data of this kind are significant in life insurance. The results are related not only to adverse health problems, but also to social problems, such as determining the fatness of the population of different regions.*

Keywords: *fuzzy logical, Mamdani method, degree of obesity of body mass, production rules, fuzzy inference*

Introduction

During the last centuries, the accumulation of excessive fat in the body was recognized as a social and medical problem and was considered an independent factor determining life expectancy. Obesity is a growing threat to global health due to its association with insulin resistance, inflammation, hypertension, and dyslipidemia, collectively known as metabolic syndrome. From an anatomical and metabolic point of view, the term obesity refers to the excessive accumulation of fat in the body [1]. Gender, age, ethnic group are important variables in it. 10-15 % excess weight in men and 20-25 % in women is a sign of obesity. It is important to study the risk of obesity to determine the risk of developing hormonal and metabolic changes in the body, as well as other diseases [2].

In new medical terminology body mass index (BMI), waist circumference size (WCS), degrees of abdominal obesity (DAO) are direct factors for measuring the degree of obesity of body weight (OBW).

BMI- is a metric of the ratio of a person's height and weight, which is used to determine static and dynamic anthropometric characteristics in humans. BMI is determined by dividing a person's body weight (kg) by the square of their height (m2). For a long time, BMI was considered a factor in determining the proportion of body fat. Nowadays, it has been identified a problem with BMI as an indicator of obesity. BMI has serious limitations when used as an indicator of body fat percentage. Because it cannot differentiate between lean body mass and fat mass; a person with a high BMI may have a very low-fat mass and vice versa [3].

WCS is a measure of the fat around a person's belly – this is called visceral fat, which surrounds the liver and other organs in the abdomen. This type of fat is metabolically active, releasing fats, hormones, and other inflammatory chemicals into your blood. This ongoing inflammation is thought to play a role in many chronic diseases, including heart disease and diabetes [4; 5].

DAO is a metabolic disorder caused by excessive accumulation of fat deposits not only in the subcutaneous fat tissue but also in the abdominal cavity and muscles. This is the most dangerous type of obesity, as fat that accumulates around the main organs of the body interferes with their functioning. The location of adipose tissue allows identifying pathological changes in the human body. To determine abdominal obesity, you need to calculate the ratio between the waist circumference and the hip. Having found abdominal obesity, you can determine the risk of developing other diseases. Waist circumference is measured in the middle of the midline between the lower edge of the chest and the middle of the femur (maximum size and not the navel area). The size of the circle of the rudiment is measured in their widest area - the size of the large bone [6].

All three factors are fuzzy parameters. In such situations, exact mathematical solutions are impossible, and the fuzzy logical inference method is used to make a decision. Where fuzzy production rules can provide an answer option for different situations. The universes of fuzzy variables of OBW, BMI, WCS, DAO are identified.

Identification and evaluation of linguistic variables

The advantage of fuzzy logic theory is that it can provide a response option for various situations where exact mathematical solutions are not possible. Clarifying linguistic meanings and even determining the truth value of fuzzy sentences remain open problems in word computing. Linguistic meanings are defined in their universes to formalize the possible positions of objects described by the linguistic meaning, which is determined by a subset of objects, using the common- sense knowledge of users [7; 8].

An important task in the application of fuzzy logic is the definition of the membership function. In this case, operations with fuzzy objects are performed by membership functions. The MATLAB system is an adapted environment for calculating membership functions [9; 10].

Linguistic terms of the BMI variable used to determine obesity rates in the universe (10,50):

BMI1 → BMI is below normal (10.2, 14.3, 18.5);

BMI 2 → BMI is normal (17.08, 21.6, 25.3);

BMI 3 → BMI slightly above normal (24.01, 27.89, 30.82);

BMI 4 → BMI above normal (30.2, 33.7, 37.9);

BMI 5 → BMI much above normal (35.89, 39.54, 43);

BMI 6 → BMI is too high (42.2, 45, 48.55).

Based on linguistic terms in MATLAB Fuzyy, a program for plotting BMI indicators was constructed (fig. 1).

Linguistic terms of the WCS variable used to determine obesity indicators:

WCS1 → WCS is small (67.04, 72.2, 75.56);

WCS2 → WCS is normal (74.9, 79, 82);

WCS3 → WCS has increased slightly (81, 96.45, 99);

WCS4 → WCS has increased (97, 100, 104.1);

WCS5 → WCS has increased significantly (102, 105, 109);

WCS6 → WCS has increased greatly (108, 111.9, 116.5).

The linguistic terms of the WCS variable are described as follows (fig. 2).

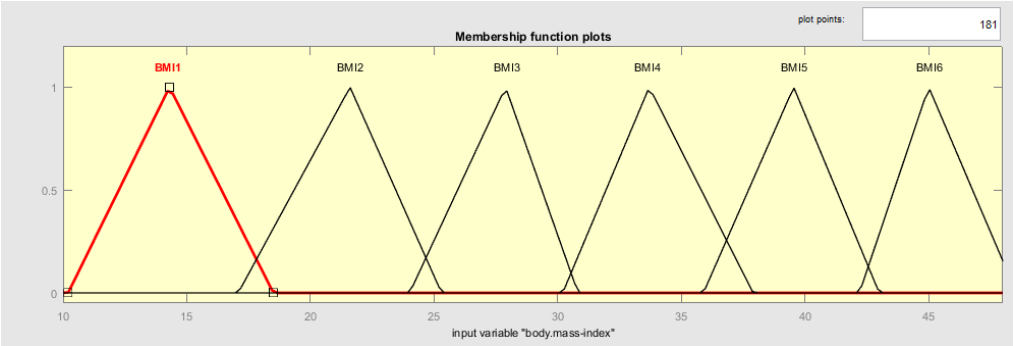

Figure 1. Graphic program of BMI term indicators

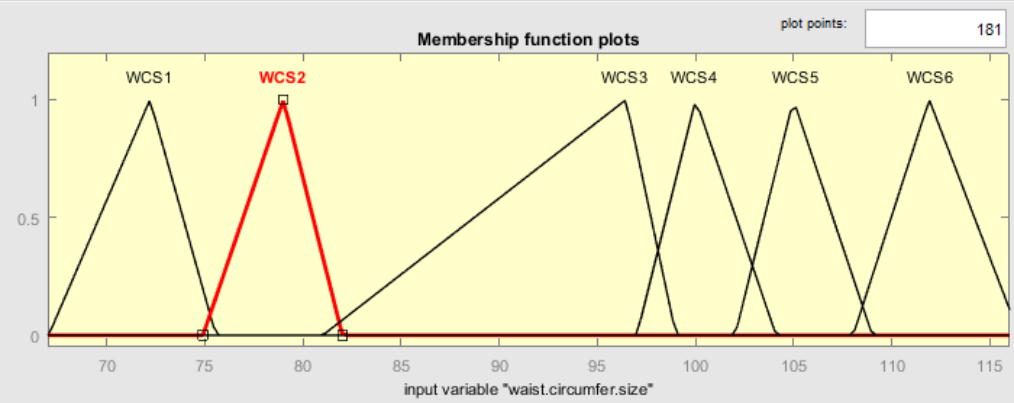

Figure 2. Graphic program of WCS term indicators

The linguistic terms of the DAO variable used to determine obesity indicators:

DAO1 → no abdominal obesity (0.24, 0.45, 0.6);

DAO2 → abdominal obesity slightly increased (0.48, 0.76, 1);

DAO3 → abdominal obesity increased (0.91, 1.34, 1.6);

DAO4 → abdominal obesity increased significantly (1.61, 1.7, 1.93);

DAO5 → abdominal obesity increased too much (1.85, 2.34, 3).

The linguistic terms of the DAO variable are described as follows (fig. 3).

The linguistic terms of the OBW variable are defined as follows:

OBW 1 → Indicates underweight (34, 37.89, 43);

OBW 2 → OBW is normal (42.45, 49.88, 55.9);

OBW 3 → Overweight (54.7, 61, 67);

OBW 4 → Indicates I degree of OBW (65, 74, 82);

OBW 5 → Indicates II degree of OBW (80, 86.2, 92.5);

OBW 6 → Indicates III degree of OBW (94, 100, 106).

The linguistic terms of the OBW variable are described as follows (fig. 4).

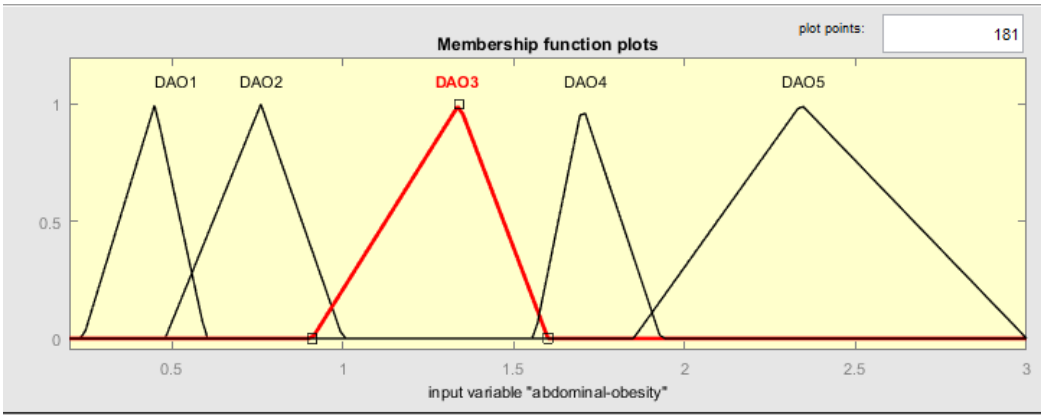

Figure 3. Graphic program of DAO term indicators

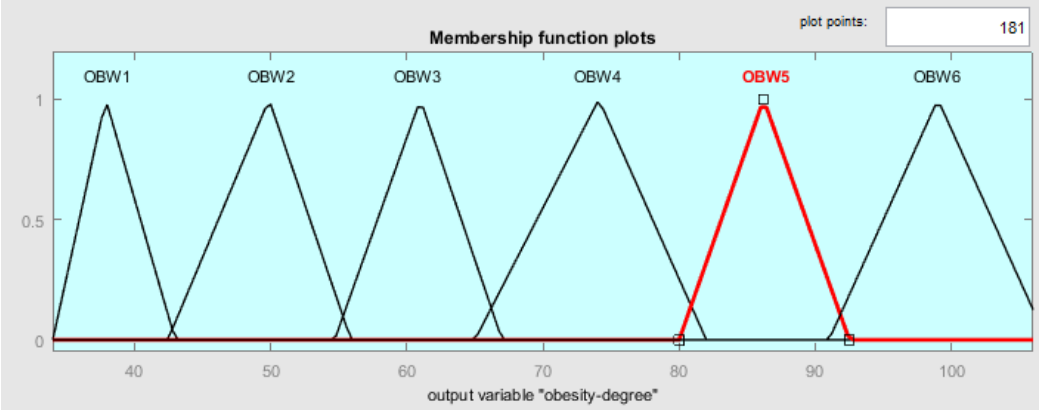

Figure 4. Graphic program of OBW term indicators

Based on the input linguistic variables BMI, WCS, DAO in MATLAB Fuzzy, a program for calculating the values of the output variable OBW was built using the Mamdani algorithm (fig. 5).

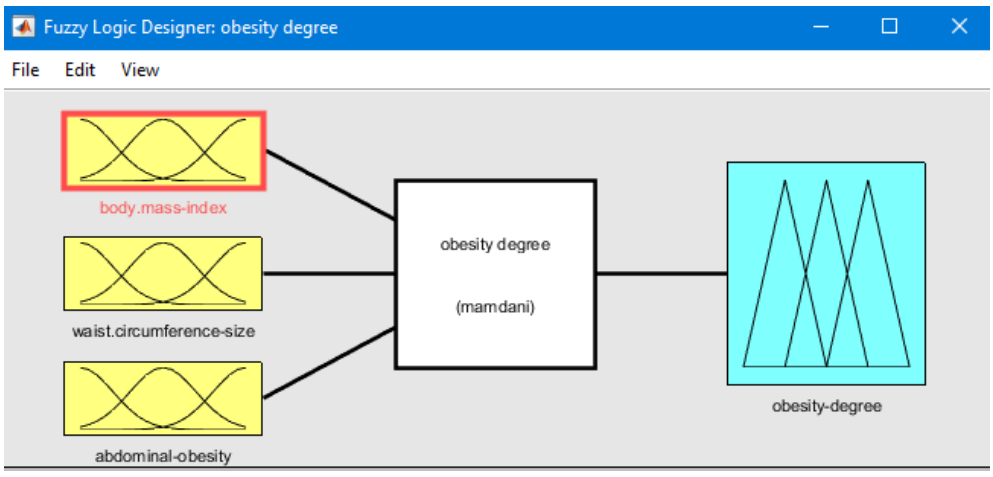

Figure 5. Structure of Mamdani Fuzzy Inference Algorithm

Computer implementation of fuzzy logical inference and conducting experiments

To implement logical inference, the following fuzzy production rules have been developed:

If BMI is BMI1 and WCS is WCS1 and DAO is DAO1 then OBW is OBW1

If BMI is BMI2 and WCS is WCS2 and DAO is DAO1 then OBW is OBW1

If BMI is BMI2 and WCS is WCS2 and DAO is DAO2 then OBW is OBW2

If BMI is BMI3 and WCS is WCS3 and DAO is DAO2 then OBW is OBW3

If BMI is BMI3 and WCS is WCS3 and DAO is DAO3 then OBW is OBW3

If BMI is BMI4 and WCS is WCS4 and DAO is DAO4 then OBW is OBW4

If BMI is BMI5 and WCS is WCS5 and DAO is DAO5 then OBW is OBW5

If BMI is BMI6 and WCS is WCS6 and DAO is DAO5 then OBW is OBW6

These rules are presented in the Fuzzy Ruler application window of the MATLAB system (fig.6).

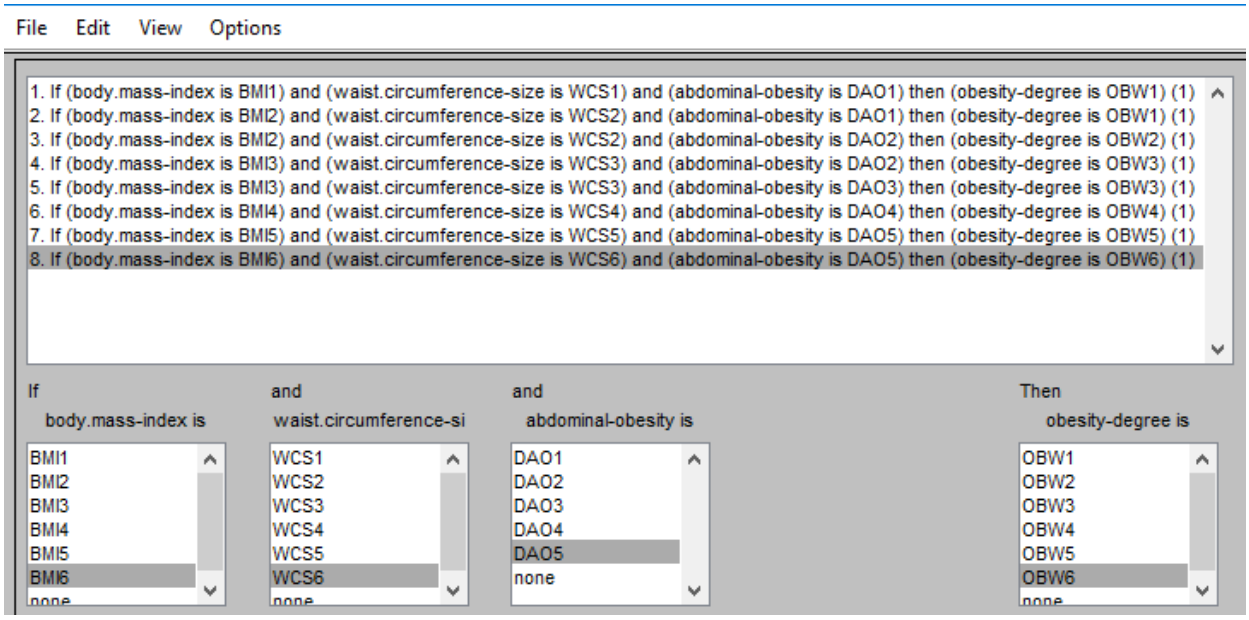

Figure 6. Fuzzy Ruler application window

The advantage of the Fuzzy Ruler app is that you can provide an answer option for different situations (fig. 7).

Below are the results of the experiments conducted in the form of graph (fig. 8).

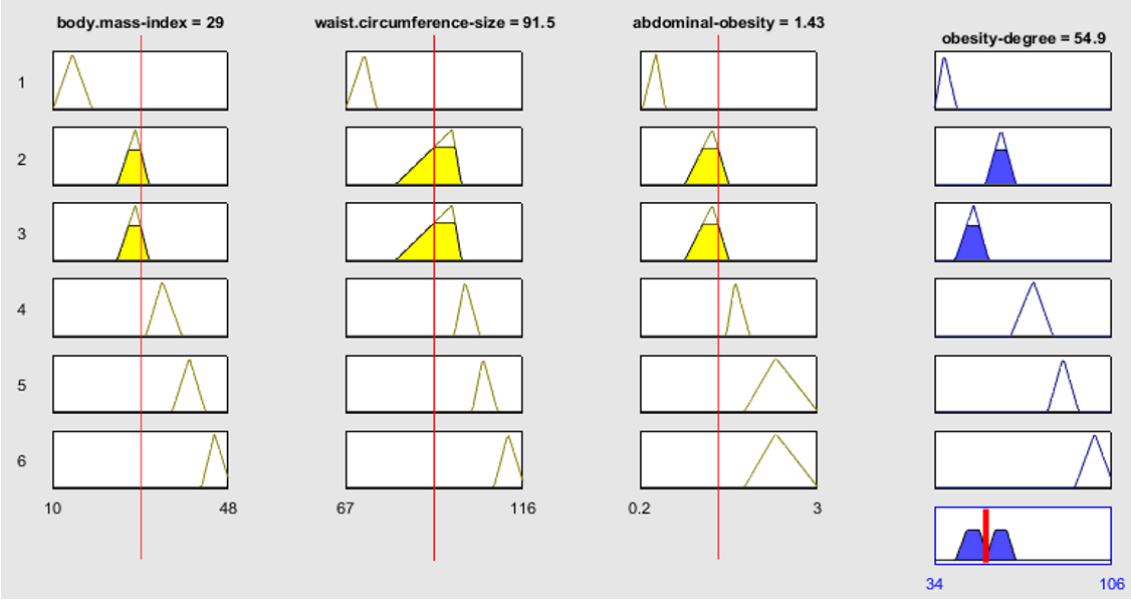

Figure 7. Conducting experiments window

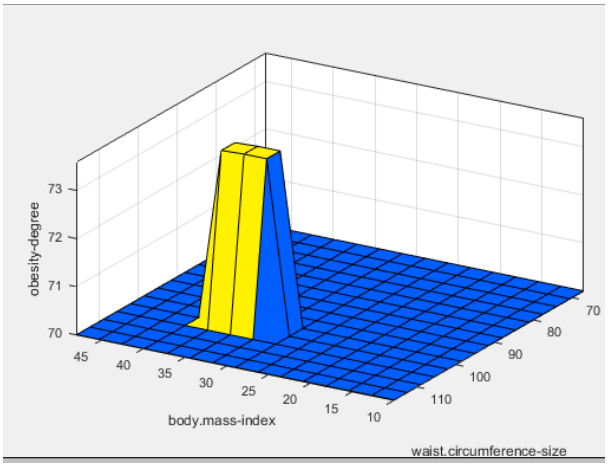

Figure 8. Experiments conducted in the form of a graph

The results of some of the experiments conducted are displayed in the table (table 1).

Table 1. Results of the conducted computer experiments

BMI	WCS	DAO	OBW
14	71.1	0.389	38.3
15.5	72.3	0.443	38.35
17.4	73	0.518	38.4
18.5	74.8	0.575	38.7
20.7	79.9	0.773	67.3
21.6	79.9	0.971	70
25.4	83.4	1.06	70.7
26.8	84.8	1.11	70.78
28.7	86.36	1.19	70.92
32.42	90.56	2.06	71.09
43.9	109	2.67	99.1
45.2	111	2.73	99.12

Conclusion

The obtained results can be used in population studies to define specific categories of body weight as a health problem. The results are related not only to adverse health problems, but also to social problems, such as determining the nutritional status of the population in different regions. The accumulated data of this kind are significant in life insurance.

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МОДЕЛИРОВАНИЕ ОПРЕДЕЛЕНИЯ СТЕПЕНИ ОЖИРЕНИЯ С ПРИМЕНЕНИЕМ МЕТОДА НЕЧЕТКОГО ЛОГИЧЕСКОГО ВЫВОДА

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Аннотация. *Статья посвящена компьютерному моделированию социальной и медицинской проблемы определения степени ожирения массы тела. Проведен анализ, выявлена значимость решения проблемы. Представлен подход к решению определения степени ожирения массы тела с применением современных математических методов опирающихся на теорию нечетких множеств и на метод нечеткого логического вывода. На основе краткого обзора сделан вывод, что индекс массы тела, размера окружности талия, степени абдоминального ожирения, являются прямыми факторами измерения степени ожирения массы тела. Так как все три факторы являются нечеткими параметрами, для принятия решения применен метод нечеткого логического вывода. Выявлены универсумы нечетких переменных ожирения массы тела, индекс массы тела, размера окружности талия, степени абдоминального ожирения. С помощью нечетких продукционных правил предоставлены варианты ответа для различных ситуаций. Нечеткий логический вывод реализован методом Мамдани. Построенная модель позволяет объективно и точно рассчитать показатели ожирения для большого количества людей за короткий промежуток времени. Благодаря этой особенности разработанный подход может быть использован в популяционных исследованиях при определении конкретных категорий массы тела как проблемы со здоровьем. Накопленные этого рода данные имеют значимость при страховании жизни. Результаты связаны не только с неблагоприятными проблемами со здоровьем, но и с социальными проблемами, такими как определение упитанности населения разных регионов.*

Ключевые слова: *нечеткая логика, метод Мамдани, степень ожирения массы тела, продукционные нечеткая логика правила, нечеткий логический вывод*

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