FUZZY TOPSIS APPROACH IN IDENTIFICATION OF AGE GROUP IN WOMEN WITH DIABETES

[1] S. Santhosh, [2] Shubham Kumar, [3] Chandana Venkatesh and [4] G.K.Revathi

Division of Mathematics, School of Advanced Sciences, Vellore Institute of Technology Chennai, Chennai 127, Tamil Nadu, India.

[1]ssan04391@gmail.com, [2]slatterhenry384@gmail.com, [3] chandana639@gmail.com and [4]gk_revathi@yahoo.co.in

ABSTRACT:

The main objective of this article is to clarify which age group of females is most impacted by diabetes. To achieve the Resulting Analysis, the TOPSIS Methodology is applied. For this purpose, including age, glucose, pregnancy, blood pressure, skin thickness, insulin, body mass index, and diabetes pedigree function of females were considered to predict the age group in women who are affected by diabetes the most using "TOPSIS"- Multi-Criteria Decision-Making (MCDM) techniques.

Key Word: MCDM Method, Fuzzy Logic, Diabetic Women

INTRODUCTION

Fuzzy MCDM techniques provide more realistic impacts in problem-solving situations. Lotfi Zadeh of the University of California at Berkeley introduced the concept of fuzzy logic for the first time in the 1960s [1]. In recent years, fuzzy logic has seen a considerable rise in the number and variety of applications. Fuzzy reasoning is based on straightforward mathematical ideas. Without the extensive intricacy, fuzzy logic is a more understandable method. In normal logic, all assertions have a truth value of one or zero. Fuzzy logic is a generalisation of this. Using the [0, 1] range, statements in fuzzy logic can have a partial truth value of 0.9 or 0.5. Fuzzy logic is employed in a wide variety of applications today, including artificial intelligence, commercial decision-making, industrial processes, and aeronautical engineering [2]. A method for evaluating issues with a finite or infinite number of options is called multiple criteria decision making (MCDM) [3]. Figure 3 demonstrates the fundamental design of MCDM techniques.

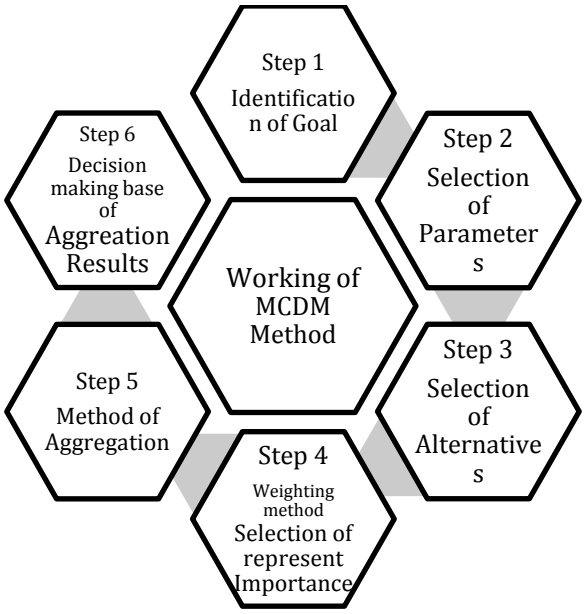

Figure 1

MCDM is a subfield of operations research (or), and it has the potential to enhance engineering decision-making in all areas, from design to manufacture. However, it is especially helpful for applications in high-technology market sectors, where product differentiation and competitive advantage are frequently attained by just very small gains in material performance [4]. Both traits and objectives can be used as criterion. According on the nature of the problems, various writers divide MCDM approaches into two groups. Multi-objective and multi-attribute decision making (MCDM) (MCDM) [5]. The multi-criteria decision analysis approach known as The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was first created by Ching-Lai Hwang and Yoon in 1981. Yoon made additional improvements in 1987 and 1993, along with Hwang, Lai, and Liu. The foundation of TOPSIS is the idea that the final solution should be the one with the least geometric distance from the positive ideal solution (PIS) and the greatest geometric distance from the negative ideal solution (NIS).

Essentially, diabetes, also known as diabetes mellitus, is a fatal, chronic, and troublesome disorder. It is a metabolic disorder in which the body is unable to effectively make or utilise insulin, a hormone required to transform sugar, carbohydrates, and other foods into the energy required for daily life. This research primarily addresses how diabetes develops in women, as stated in the abstract. Compared to males, women have a roughly four-fold increased risk of developing diabetes, whereas men only have a two-fold increase. An investigation found that Asian/Pacific Islander, American Indian/Alaska Native, African American, and Hispanic/Latina women have higher rates of diabetes than white women. One of the most prevalent illnesses in the US is this one [6]. 5.4 million of the 16 million Americans who have diabetes are unaware of their condition. Who estimates that in 2019, the disease caused the deaths of 1.5 million individuals, according to the records [6]. In general, diabetes, also known as diabetes mellitus, is a fatal and complicated condition. It is a metabolic disease where the body cannot properly produce or use the hormone insulin, which is required to turn sugar, starches, and other foods into the energy we need for daily life. In general, there are two types: type 1 and type 2. The real difference between type-1 and type-2 is that type-1 is a genetic condition that frequently manifests in early life, whereas type-2 is primarily related to lifestyle and manifests over time. There is also a condition known as gestational diabetes, which is another form of the disease [10]. An autoimmune disease called type 1 diabetes develops when the body's immune system attacks the beta cells that reside in the pancreatic tissue. People with type 1 diabetes cannot distribute glucose to body cells properly because their pancreas is not functioning properly. Any autoimmune disorder, not just type 1 diabetes, may be more dangerous for someone with a family history of it. Type 1 diabetes may also be related to specific viruses or diseases. About 5–10% of people with diabetes have type 1 diabetes, which is less prevalent than type 2 diabetes [19]. As a result of the way that it manifests in the body after a change in lifestyle, type 2 diabetes is also known as "adult-onset diabetes." In essence, it happens when blood sugar, also known as glucose, rises to an unhealthy level. Insulin is either poorly produced by the body or poorly used. At Any Age, Even During Childhood, Type-2 Diabetes Can Develop. However, Middle-Aged and Older People Are Most Prone to It. Most cases of diabetes (around 90%) are type 2; the other 10% are primarily caused by type 1 and gestational diabetes. As of 2015, 392 million people had been diagnosed with the disease, up from about 30 million in 1985 [20]. Type 1: Urination Issues (Frequently Urinating), Cloudy Vision, Constant Hungry (Even When Eating More), Increase in Thrust, Increase in Fatigue. (Experienced A Weariness). Type 2 symptoms include unusual weight loss, frequent infections, tingling, pain, or numbness in the hands or feet, as well as slow healing cuts and bruises. Gestational: There are no symptoms of gestational diabetes. However, some conditions, such feeling thirsty or fatigued, can be viewed as symptoms [21]. A person with type 1 diabetes requires daily insulin injections. Calculate the diet before starting it. I.e., a balance of carbohydrates, proteins, and fats should be present [16]. A study found that approximately 40% of type 2 diabetes patients needed insulin injections. Metformin, Insulin, SGLT-2 Inhibitors, GLP-1 Resistor Agonists, DPP-4 Inhibitors, Combination Drugs, Sulfonylureas, and Tzds Are Typically Used To Treat Type 2 Diabetes [17]. Diabetes symptoms

include frequent urine problems, hazy vision, continuous hunger (even after eating more), increased push, and increased weariness. (Feeling of being fatigued), pain or numbness in the hands or feet, progressive weight loss, infections Some circumstances, such as being weary or thirsty, might be thought of as symptoms. Women Who Walk More Than 10,000 Steps Per Day Have A Lower Risk Of Type 2 Diabetes. [7] In the upcoming years, it is anticipated that India's diabetic patient population would grow significantly. The fundamental concepts of managing diabetes are the same for both men and women, despite possible differences in symptoms and treatments. [8] According to data from a recent study, those with a history of gestational diabetes who regularly drink coffee have a lower risk of developing type 2 diabetes. [9]

Gestational diabetes is a form of glucose intolerance that is the most prevalent metabolic complication of pregnancy. It is not immediately apparent before becoming pregnant and is diagnosed in the second or third trimester. Analyses of pregnant diabetic women's quality of life are done in the paper. Using SPSS software 25 to do a descriptive study [11], In women with CF, gestational and pregestational diabetes are extremely common. Diabetes affects foetal outcomes, and good glycaemic control lowers the risk of complications during pregnancy. Gestational and pregestational diabetes in pregnant women with cystic fibrosis is the primary goal of the paper [12]. There are disparities in access to care for the more than 12 million minority and low-income women who have type 2 diabetes (T2DM) in the US, which has a negative impact on their health outcomes. The paper's main objective is to educate minority women about diabetes self-management using online resources. With the aid of information acquired from women in control 2.0, a mixed study is carried out here (WIC2) [13], The Diabetes Remission Clinical Trial (Direct) has demonstrated that weight loss with a total diet replacement (TDR) along with ongoing behavioural support can result in a sustained remission of type 2 diabetes in primary care. The paper's main objectives are to comprehend the process of behaviour change, support application into healthcare, and aid in the intervention's optimization. The study's foundation is a qualitative examination [14]. The cornerstone of diabetes care is exercise, yet adherence is low and maintaining physical activity is still difficult. The paper's main objective is to treat T2DM patients through exercise and the development of new, straightforward activities [15]. Maternal hyperglycaemia now affects one in every six pregnancies worldwide, and the prevalence of gestational diabetes mellitus (GDM), which has historically been defined as glucose intolerance of varying severity with first onset in pregnancy, is rising. The paper's main objective is to open up prospects for women's diabetes and heart disease prevention [18]. There are several medical health programmes available today to manage health, but it can be difficult to determine which is the most user-friendly. Researchers concentrated on the hybrid approach to deliver accurate results. The paper's primary objective is to inform readers about the top mobile health applications. The paper employs the MCDM approach [22]. The development of self-management mHealth applications is crucial given the current doctor to patient ratio in our nation (1:1700, according to a Times of India study in 2021). In order to increase customer satisfaction, it is necessary to guarantee that mHealth applications are straightforward and user-friendly. The paper's principal objective is to assess the importance of each diabetic complication considering its primary risk factors. It uses fuzzy TOPSIS and fuzzy grey relation analysis, both of which fall under the MCDM umbrella [23], An important global public health issue is type-2 diabetes. Because of its complications, which include heart and blood vessel disorders as well as kidney-related problems, etc., this disease needs to be effectively handled [24], The "Standards of Care in Diabetes" by the American Diabetes Association (ADA) contain the organization's most recent clinical practise recommendations and are designed to give patients access to diabetes care components, general treatment goals and guidelines, and tools for assessing the quality of care. The paper focuses mostly on a few mHealth applications that help patients manage type 2 diabetic mellitus (T2DM) on their own. In this work, MCDM was the methodology. With the prevalence of type 1 diabetes (T1D), type 2 diabetes (T2D), and gestational diabetes rising, more women are anticipated to live with a diabetes diagnosis for a greater percentage of their reproductive years. The study's major goal is to shorten the time during which women with

diabetes must live with a diagnosis. The Canadian Longitudinal Study on Aging's Comprehensive Cohort data were used.

The current situation of rising diabetes cases in the female population has influenced the structure of this article. In recent years, there has been a sharp rise in instances, according to studies from the WHO and many other health organizations, as a result of changing lifestyles. Diabetes is explained in a way that includes its forms, symptoms, causes, the experience of women with diabetes, as well as the therapy. After reading a literature review and a few news articles about diabetes in women, the author of this paper focused on determining the age group of females who are most affected by the disease using the fuzzy logic multi-criteria decision-making method of the TOPSIS ranking method. The paper also included a dataset on diabetes in which the scale point was fixed using linguistic values some beneficial and non-beneficial attributes are mentioned according to the weightage. The ranking result was eventually discovered, and visualization was displayed using the R programming language. The major contribution of this paper as follows

1. Using the average approach, the acquired dataset is categorized by age wise.
2. For the impacted diabetes patient's dataset, linguistic values are provided.
3. The scale point is fixed based on linguistic values, and the weighting of beneficial and non-beneficial value is fixed based on the dataset.
4. With the use of the TOPSIS approach, the dataset's final ranking is established.
5. Using R and the provided syntax, the visualization result is determined.

2 ALGORITHMS

Step 1: Data collection

Step 2: Data categorize to simplify the dataset

Step 3: Fixing scale point with respect to linguistic values

Step 4: Fixing the weightage, beneficial and non-beneficial of the simplified dataset

Step 5: Find ranking using Multi Criteria decision method of TOPSIS method

3 IMPLEMENTATIONS

Diabetes has become a common problem in daily life. According to the research review, women were more severely impacted than men. The TOPSIS ranking algorithm, categories data, dataset, linguistic values, scale points, weightage, benefit, and normalization, as well as a graphical representation created using R-studio, are used to determine which age group of females is most affected in this paper.

Step 1: Categorize Dataset

Case 1: The Dataset Was Obtained From The Web https://www.kaggle.com/code/rrahulvarma/diabetes-data/data.

Case 2: The dataset from step 1, which contains the records of 768 women, was gathered to determine which age group of women was affected by diabetes. The Dataset is shown in the table 1,

Pregnancies	Glucose	Blood Pressure	Skin Thickness	Insulin	BMI	Diabetes	Age
1	89	66	23	94	28.1	0.167	21
1	73	50	10	0	23	0.248	21
…	…	…	…	…	…	…	…
….	…	…	…	…	…	…	…
5	136	82	0	0	0	0.64	69
4	145	82	18	0	32.5	0.235	70

Table 1

Step2: The dataset was categorized by determining the average for each age group, as shown in table 2.

AGE	GLUCOSE	PREGNANCIES	BLOOD PRESSURE	SKIN THICKNESS	INSULIN	BMI	DIABETES PEDIGREE FUNCTION
21-25	110.7293	1.537594	63.81955	22.04135	84.64286	30.37519	0.457545
26-30	120.3221	2.818792	67.98658	21.33557	84.05725	33.08255	0.43055
31-35	124.3625	4.4875	69.125	20.1	92.3625	32.91625	0.61585
36-40	128.3625	6.106667	71.74667	20.933333	60.02667	33.01733	0.450507
41-45	124.6667	7.04	73.22	18.7333	57.45333	35.33733	0.452187
46-50	123.5	7.305556	78.3611	20.9444	69.5	33.10278	0.461333
51-55	141.5	6.33333	82.3333	15.766667	108.733	31.993377	0.508467
56-60	138.7727	6.772727	76.95455	19.22727	141.5	30.70909	0.5715
61-65	139	4.692308	69.19709	18.69231	28.46154	29.19231	0.412769
66-70	139	4.909091	80.72727	1.636364	0	27.51818	0.462545

Table 2: Simplified Dataset

Now, the figure 1 displays a graphic representation of step 2

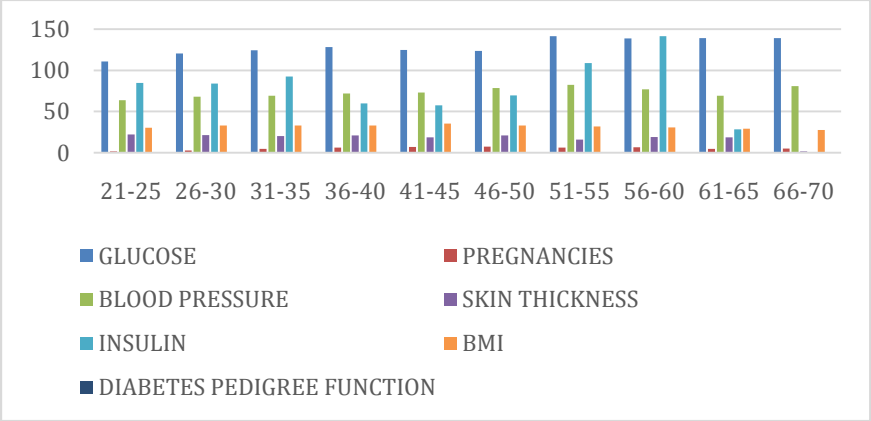

Figure 2: Graphical representation of Simplified Dataset

Step 3: Choosing Scale Point

Case 1: By consider the column of affected diabetes, the possibility of diabetes where fixed with the linguistic of the range [0,1] as shown in the table 3

LINGUSTIC VALUE FOR THE POSSIBILITY OF DIABETES	
Very low	$0 \leq POD \leq 0.34$
Low	$0.35 \leq POD \leq 0.44$
Normal	$0.45 \leq POD \leq 0.49$
High	$0.50 \leq POD \leq 0.59$
Very high	$POD \geq 0.6$

Table 3

Case 2: Table 4 displays the linguistic values for the Affected Diabetes Patient as determined in step 1

AGE	AFFECTED BY DIABETES	LINGUISTIC VALUE OF POD
21-25	0.169173	Very low
26-30	0.302013	Low
31-35	0.5125	High
36-40	0.466667	Normal
41-45	0.57333	High
46-50	0.5277778	High
51-55	0.66667	Very high
56-60	0.454545	Normal
61-65	0.230769	Very low
66-70	0.363636	Low

Table 4: Linguistic Values

Case 3: Scale point values are designed based on the linguistic values

Linguistic Value	Scale Point
Very low	1
Low	2
Normal	3

High	4
Very high	5

Table 5: Scale Point

Case 4: Based on the linguistic values, the scaling point for the simplified dataset in Table 2 is indicated in table 6

SCALE POINT	AFFECTED BY DIABETES	LINGUISTIC VALUE OF POD
1	0.169173	Very low
2	0.302013	Low
4	0.5125	High
3	0.466667	Normal
4	0.57333	High
4	0.5277778	High
5	0.66667	Very high
3	0.454545	Normal
1	0.230769	Very low
2	0.363636	Low

Table 6

Step 4: Fixing the weightage, beneficial and non-beneficial of the simplified dataset. The following step discusses the weighting, beneficial and non-beneficial value of the simplified dataset used to determine the ranking using the TOPSIS approach.

Case 1: Determine the weighting for the factors such as blood sugar, pregnancies, blood pressure, skin thickness, insulin, scale point, body mass index, and diabetes pedigree function as stated in table 6.

FACTORS	WEIGHTAGE
Glucose	0.125
Pregnancies	0.125
Blood Pressure	0.125
Skin Thickness	0.125
Insulin	0.125
Scale Point	0.125
BMI	0.125
Diabetes pedigree function	0.125

Table 6: Weightage

Case 2: The terms "beneficial" and "non-beneficial" refer to features that give more significance to certain factors and less weight to others. In the case of diabetes, the insulin level determines whether the person has the diabetes rather than the other components. As indicated in table 7, insulin is defined as beneficial in this paper whereas the other components are defined as not beneficial.

FACTORS	BENEFICIAL/NON-BENEFICIAL
Glucose	Non-Beneficial
Pregnancies	Non-Beneficial
Blood Pressure	Non-Beneficial

Skin Thickness	Non-Beneficial
Insulin	Beneficial
Scale Point	Non-Beneficial
BMI	Non-Beneficial
Diabetes pedigree function	Non-Beneficial

Table 7: Beneficial/Non-Beneficial

Case 3: In order to make all factor comparable, the normalization process can be calculated. There are two types of formula to calculate the normalization for the beneficial and non-beneficial for the TOPSIS method for the MCDM method such that,

$$Benifical = \frac{x_{ij}}{Max\,(x_{ij})} \text{ and } Non\,Benifical = \frac{min\,(x_{ij})}{x_{ij}}$$

AGE	GLUCOSE	PREGNANCIES	BLOOD PRESSURE	SKIN THICKNESS	INSULIN	BMI	DIABETES PEDIGREE FUNCTION	SCALE POINT
21-25	1	1	1	0.07424	0.598	0.90594	0.90214	1
26-30	0.9203	0.5455	0.9387	0.0767	0.594	0.8318	0.9587	0.5
31-35	0.8904	0.3426	0.9232	0.08141	0.653	0.83601	0.67024	0.25
36-40	0.8626	0.2518	0.8895	0.07817	0.424	0.83345	0.91623	0.3333333
41-45	0.8882	0.2184	0.8719	0.08735	0.406	0.77873	0.91283	0.25
46-50	0.001	0.0171	0.0016	0.00597	0.491	0.8313	0.89473	0.25
51-55	0.7825	0.2428	0.7751	0.10379	0.768	0.86012	0.81179	0.2
56-60	0.7979	0.227	0.8293	0.08511	1	0.89609	0.72226	0.3333333
61-65	0.7966	0.3277	0.9223	0.08754	0.201	0.94265	1	1
66-70	0.7966	0.3132	0.7906	1	0	1	0.89239	0.5

Table 8: Normalization

Step 4: Ranking

The primary objective of this study is to identify the age group of females affected by diabetes using the ranking method of TOPSIS method in the manner described in the stages below,

Case 1: As indicated in table 9, the weightage value is multiplied by the normalised dataset.

AGE	GLUCOSE	PREGNANCIES	BLOOD PRESSURE	SKIN THICKNESS	INSULIN	BMI	DIABETES PEDIGREE FUNCTION	SCALE POINT
21-25	0.125	0.125	0.125	0.00928	0.074773	0.113243	0.112767323	0.125
26-30	0.115034	0.068185	0.117339	0.009587	0.074256	0.103975	0.119837708	0.0625
31-35	0.111297	0.04283	0.115406	0.010176	0.081592	0.104501	0.083780344	0.03125
36-40	0.107831	0.031474	0.111189	0.009771	0.053027	0.104181	0.11452902	0.041666667
41-45	0.111025	0.027301	0.108981	0.010919	0.050754	0.097341	0.114103512	0.03125
46-50	0.000127	0.002139	0.000199	0.000746	0.061396	0.103912	0.111841392	0.03125
51-55	0.097817	0.030347	0.096892	0.012973	0.096054	0.107515	0.101473891	0.025
56-60	0.09974	0.028378	0.103664	0.010638	0.125	0.112012	0.090281934	0.041666667
61-65	0.099577	0.028378	0.115286	0.010943	0.025143	0.117831	0.125	0.125
66-70	0.099577	0.039152	0.09882	0.125	0	0.125	0.111548336	0.0625

Table 9: Normalization*Weightage

Case 2: As seen in table 10, the total value is determined for each row in accordance with the age group that is specified

AGE	GLUCOSE	PREGNANCIES	BLOOD PRESSURE	SKIN THICKNESS	INSULIN	BMI	DIABETES PEDIGREE FUNCTION	SCALE POINT	TOTAL
21-25	0.125	0.125	0.125	0.00928	0.074773	0.113243	0.112767323	0.125	0.810063
26-30	0.115034	0.068185	0.117339	0.009587	0.074256	0.103975	0.119837708	0.0625	0.670713
31-35	0.111297	0.04283	0.115406	0.010176	0.081592	0.104501	0.083780344	0.03125	0.580833
36-40	0.107831	0.031474	0.111189	0.009771	0.053027	0.104181	0.11452902	0.041666667	0.573668
41-45	0.111025	0.027301	0.108981	0.010919	0.050754	0.097341	0.114103512	0.03125	0.551675
46-50	0.000127	0.002139	0.000199	0.000746	0.061396	0.103912	0.111841392	0.03125	0.31161
51-55	0.097817	0.030347	0.096892	0.012973	0.096054	0.107515	0.101473891	0.025	0.568073
56-60	0.09974	0.028378	0.103664	0.010638	0.125	0.112012	0.090281934	0.041666667	0.611381
61-65	0.099577	0.028378	0.115286	0.010943	0.025143	0.117831	0.125	0.125	0.647158
66-70	0.099577	0.039152	0.09882	0.125	0	0.125	0.111548336	0.0625	0.661596

Table 10: Total Value of Table

Case 3: Ranking is given accruing to the result of total value, from minimum to maximum as shown in the table of 11

AGE	GLUCOSE	PREGNANCIES	BLOOD PRESSURE	SKIN THICKNESS	INSULIN	BMI	DIABETES PEDIGREE FUNCTION	SCALE POINT	TOTAL	RANKING
21-25	0.125	0.125	0.125	0.00928	0.074773	0.113243	0.112767323	0.125	0.810063	1
26-30	0.115034	0.068185	0.117339	0.009587	0.074256	0.103975	0.119837708	0.0625	0.670713	2
31-35	0.111297	0.04283	0.115406	0.010176	0.081592	0.104501	0.083780344	0.03125	0.580833	6
36-40	0.107831	0.031474	0.111189	0.009771	0.053027	0.104181	0.11452902	0.041666667	0.573668	7
41-45	0.111025	0.027301	0.108981	0.010919	0.050754	0.097341	0.114103512	0.03125	0.551675	9
46-50	0.000127	0.002139	0.000199	0.000746	0.061396	0.103912	0.111841392	0.03125	0.31161	10
51-55	0.097817	0.030347	0.096892	0.012973	0.096054	0.107515	0.101473891	0.025	0.568073	8
56-60	0.09974	0.028378	0.103664	0.010638	0.125	0.112012	0.090281934	0.041666667	0.611381	5
61-65	0.099577	0.028378	0.115286	0.010943	0.025143	0.117831	0.125	0.125	0.647158	4
66-70	0.099577	0.039152	0.09882	0.125	0	0.125	0.111548336	0.0625	0.661596	3

Table 10: Ranking of Diabetic Women with Age-Based Categories

4 RESULT AND VISUALIZATION

Utilizing the R programming language, a 2-D graph is created to visualize the women's age group in connection to the ranking using the TOPSIS method's multi-criteria decision-making process. The result's syntax and visualization are shown in figure 3. This R code is used to plot the graph to show the age distribution of women getting diabetes. For that average of women age and our rank is taken as input. The plot function is used to plot the 2-D graph. The polygon function is used to draw the lines and coloring to the graph.

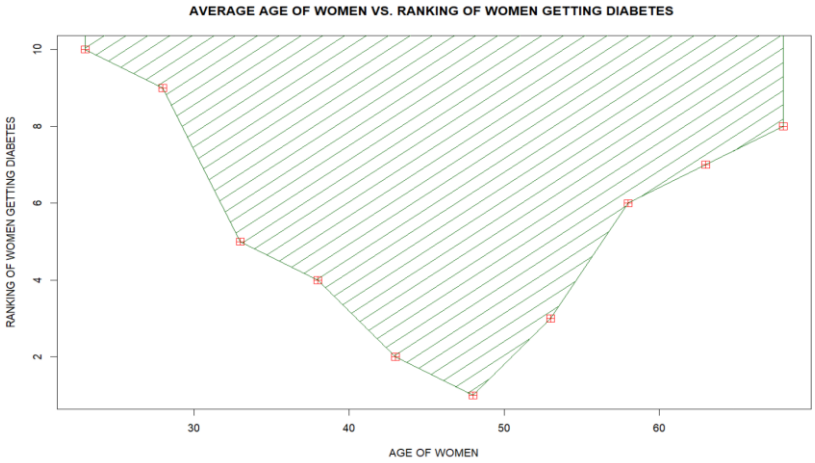

Figure 3: Result and Visualization

Conclusion

From figure 3, it is evident that women between the ages of 20 and 25 have a higher risk of developing diabetes. Diabetes can be prevented by a variety of healthy lifestyle strategies. Through counselling and support programs, food and exercise are combined to help women lose weight, lower their systolic blood pressure, improve their cholesterol levels, and reduce their risk of developing diabetes.

Funding

Authors don't have funding support.

Availability of data and materials

Authors have no data and materials.

Ethics approval and consent to participate

Not applicable.

Competing interests

Not applicable.

Authors Contributions

All authors contributed equally.

Reference

[1] Sugeno, Michio, and Takahiro Yasukawa. "A fuzzy-logic-based approach to qualitative modeling." IEEE Transactions on fuzzy systems 1.1 (1993): 7-31.

[2] Bělohlávek, Radim, Joseph W. Dauben, and George J. Klir. Fuzzy logic and mathematics: a historical perspective. Oxford University Press, 2017.

[3] Lin, Laikuang, Yimin Xia, and Dun Wu. "A hybrid fuzzy multiple criteria decision-making approach for comprehensive performance evaluation of tunnel boring machine disc cutter." Computers & Industrial Engineering 149 (2020): 106793.

[4] Triantaphyllou, Evangelos. "Multi-criteria decision making methods." Multi-criteria decision making methods: A comparative study. Springer, Boston, MA, 2000. 5-21

[5] Mdpi And Acs Style Gupta, K.; Roy, S.; Poonia, R.C.; Kumar, R.; Nayak, S.R.; Altameem, A.; Saudagar, A.K.J. Multi-Criteria Usability Evaluation Of Mhealth Applications On Type 2 Diabetes Mellitus Using Two Hybrid Mcdm Models: Codas-Fahp And Moora-Fahp. Appl. Sci. 2022, 12, 4156.

[6] Reece, E. Albert, Donald R. Coustan, and Steven G. Gabbe, eds. Diabetes in women: adolescence, pregnancy, and menopause. Lippincott Williams & Wilkins, 2004.

[7] https://www.healthline.com/health-news/type-2-diabetes-intermittent-fasting-may-help-reverse-condition

[8] https://www.hindustantimes.com/lifestyle/health/tips-to-manage-diabetes-in-men-and-women-101670487103022.html

[9] https://www.medicalnewstoday.com/articles/type-2-diabetes-intermittent-fasting-could-reverse-the-condition

[10] Brown, Adam, and Kelly L. Close. Bright spots & landmines: the diabetes guide I wish someone had handed me. San Francisco, Calif.: diaTribe Foundation, 2017.

[11] Abolfathi, Mitra, et al. "Evaluation of quality of life in diabetic pregnant women." Primary Care Diabetes 16.1 (2022): 84-88.

[12] Oxman, Rachael, et al. "Gestational and pregestational diabetes in pregnant women with cystic fibrosis." Journal of Clinical & Translational Endocrinology 27 (2022): 100289.

[13] Mitchell, Suzanne, et al. "Patient engagement and presence in a virtual world world diabetes self-management education intervention for minority women." Patient education and counseling 105.4 (2022): 797-804.

[14] Rehackova, Lucia, et al. "Participant experiences in the diabetes REmission clinical trial (DiRECT)." Diabetic medicine 39.1 (2022): e14689.

[15] Nielsen Sg, Danielsen Jh, Grønbæk Hn, Molsted S, Jacobsen Ss, Vilsbøll T, Varming Ar. Transforming Motivation For Exercise In A Safe And Kind Environment—A Qualitative Study Of Experiences Among Individuals With Type 2 Diabetes. International Journal Of Environmental Research And Public Health. 2022; 19(10):6091.

[16] The Ultimate Guide To Accurate Carb Counting – Gary Scheiner (I)

[17] Vijan, Sandeep. "Type 2 diabetes." Annals of internal medicine 152.5 (2010): ITC3-1.

[18] Fu, Jennifer, and Ravi Retnakaran. "The life course perspective of gestational diabetes: An opportunity for the prevention of diabetes and heart disease in women." EClinicalMedicine 45 (2022): 101294.

[19] Egan, Aoife M., and Seán F. Dinneen. "What is diabetes?." Medicine 47.1 (2019): 1-4.

[20] Tuomi, Tiinamaija. "Type 1 and type 2 diabetes: what do they have in common?." Diabetes 54.suppl_2 (2005): S40-S45.

[21] A Practical Guide To Diabetes Mellitus Hardcover By Nihal Thomas

[22] Gupta, K.; Roy, S.; Poonia, R.C.; Kumar, R.; Nayak, S.R.; Altameem, A. ; Saudagar, A.K.J. Multi-Criteria Usability Evaluation of mHealth Applications on Type 2 Diabetes Mellitus Using Two Hybrid MCDM Models: CODAS-FAHP and MOORA-FAHP. Appl. Sci. 2022, 12, 4156.

[23] Ebrahimi M, Ahmadi Kh. Diabetes-related complications severity analysis based on hybrid fuzzy multi-criteria decision-making approaches. Iran J Med Inform. 2017; 6(1): 11-22.

[24] Gupta, K.; Roy, S.; Poonia, R.C.; Nayak, S.R.; Kumar, R.; Alzahrani, K.J.; Alnfifiai, M.M.; Al-Wesabi, F.N. Evaluating the Usability of mHealth Applications on Type 2 Diabetes Mellitus Using Various MCDM Methods. Healthcare 2022, 10, 4.