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RESEARCH ARTICLE

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EXPERT SYSTEM USING AHP TO SUGGEST DIET TO THE DIABETICS IN ORDER TO CONTROL BLOOD SUGAR LEVEL OF THE PATIENT

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ABSTRACT

Diabetics have a specific level of blood glucose in their body which is measured by mg/dl; however this specific blood glucose level stays only for a particular day. Diabetics' blood glucose level can be up and down based on the diet they are consuming throughout their day, week or even monthly basis. Therefore in order to control the blood glucose level of the diabetic patient, the diet intake by the patient should be taken care since their life is dependent on the diet intake and the activities they are doing. The main aim of this research is to recommend the most appropriate types of diets to the diabetic patient by analyzing the nutritional facts of diets using Analytical hierarchy process (AHP) method. During the development of this research I acquired several numbers of alternative diets and the nutritional facts of the diet and then AHP method is applied over each diet so that the system recommends the appropriate types of diet to the patient based on the blood glucose level of the patient in order to make the blood glucose level of the patient more stable and to recover the patient from the disease.

Keywords: Analytical hierarchy process (AHP), Eigen value,Eigen vector, consistency index, Diet, Ranking, Mapping, etc.

1. INTRODUCTION

This research paper is intended to provide an expert system for the provision of medical advice and to recommend the most appropriate diet in order to control the blood sugar level of the diabetic patient. The main aim of this research is to recommend the most appropriate types of diets to the diabetic patient by analyzing the nutritional facts of diets using Analytical hierarchy process (AHP) method. And also this research paper will give a complete know how and information to the diabetic patient in order to help the patient to change his living life style, way of consuming diet, how much the victims has to do a physical exercise per day and etc, so that the patients will have moderate or normal blood glucose level in their body.

2. ANALYTICAL HIERARCHY PROCESS (AHP)

2.1 Introduction to Analytical Hierarchy Process (AHP)

The analytical hierarchy process (AHP) is a quantitative method for in composition alternatives and select the most efficient alternative given

multiple criteria. Based on mathematics and psychology it was formulated by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. AHP is a process which takes alternatives and criterion as input and considers ratios of each alternatives and criterion in order to paired comparison to calculate the weights. The process can use both advanced individual judgments and objective assessment just by Eigen vector and examining the reliability of the assessment by Eigen value. The combinations of individual performance indicator with one of key performance indicator are done in order to assign a different weight to each criterion or attribute.

This paper deals with the recommendation of suitable diets to the diabetic patient for each meal times of the day, it considers three meal times of the day namely: Breakfast, Lunch and Dinner times and in each meal times several number of combinations of diets are considered as alternatives. The criterion taken for these diets are: sugar, cholesterol, carbohydrate and protein which are nutritional contents of those diets. The purpose of this paper is to develop an expert system to recommend specific diet to a diabetic patient according to the patient's blood sugar level in order to control the level of sugar for the patient.

The main problems identified for this growth of diabetes all over the world includes: Shortage of specialist; the other medical staff in the Division needed expert knowledge and guidance, from the specialist, on treatment of diabetes; no commercially or free expert system is available in the area of diabetes which can recommend appropriate diet for the patient to control the blood sugar level. However, diabetes can be managed very effectively through healthy lifestyle choices, primarily by analyzing and recommending suitable diet to the patient and by choosing different activities like physical exercise. The proposed research paper will provide an expert system for the provision of medical advice and to recommend appropriate diet in order to control the blood sugar level of the diabetic patient.AHP characterizes the problem (decision situation)along with its features into order of distinctive levels as level 0, level 1, and level 2 and so on and different sub-levels as essential. These levels are made up of problem definition, criterion, and alternatives or options available. AHP can be seen to have 4 steps. First step visibly defines the goal or objective. Second step shows the criteria or factors that impact thedecision made. These criteria can be additionally set into levels and sublevels. Third steps comprise making paired comparisons of all the criteria with each other. AHP uses weighted matrix algebra to calculate Eigen vectors, Eigen values, consistencyratio (CR) and consistency index (CI). The fourth and final step of AHP is to rank the alternatives available according to the output of the method to reach the final choice. AHP is mostlygrounded on the use of Saatyscale of relative importance.

2.2 SATTY's Relative Importance Scale

Table 1 the SATTY Rating Scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favour one over the other.
5	Much more important	Experience and judgement strongly favour one over the other.
7	Very much more important	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important.	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed

Table 1 describes that AHP uses a ratio scale, which, different from methods using interval scales, which requires no units in the comparison. The judgment is a relative value or a quotient *A / B*of two quantities *A* and *B*having the same units. The decision maker does not need to provide a numerical judgment; instead a relative verbal assumption is sufficient.

The outcomes of paired comparisons for *n* attributes are structured into positive reciprocal *n* x *n* matrix.

2.3 Pair wise comparison of AHP

A basic and very reasonable assumption is that if attribute *A* is absolutely more important than attribute *B* and is rated at 9, then *B* must be absolutely less important than *A* and is valued at 1/9. If a problem which needs multi criteria decision making system having three alternatives will have the following 3*3 matrix.

Table 2 Pairwise comparison matrix

C	A_i	A_j	A_k
A_i	1	a_{ij}	a_{ik}
A_j	$\frac{1}{a_{ij}}$	1	a_{jk}
A_k	$\frac{1}{a_{ik}}$	$\frac{1}{a_{jk}}$	1

2.4 Mathematical Formulation for AHP

1. Calculate column sum of weighted matrix table as: $C_{sum} = \sum (weight_i)$,
   Where i is number of rows.
2. Divide each weight in column by their respective column sum to get normalized matrix as:
   Normalized = $weight_i/C_{sumi}$
3. Calculate the average of the rows of the normalized matrix to get Eigen Vector as:
   EigenV = ∑ (normalized-Weight/n)
   Where n is the number of rows.
4. Calculate Eigen Value (λ_{max}) by multiplying the sum of each column by Eigen vector.
   $\lambda_{max} = \sum (C_{sumi} * Egien\text{-}vector_i)$
5. Calculate consistency index (CI)
   $CI = \lambda_{max} - n/n-1$
   Where n is the number of attributes.
6. Use Random Consistency Index (RI) according to the number of attributes based on the SATTY's Random Consistency Index table.
   Table 3 Random consistency index number.

N	1--2	3	4	5	6	7	8	9
RI	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

If number of attributes (n) considered are 4,
If n = 4, RI = 0.9

7. Calculate Consistency ratio (CR) which should be less than or equal to 0.1 otherwise the output is not consistent.
   CR = CI/RI.

3 APPLYING AHP OVER THE DIETS

3.1 Diet plan datasets for diabetic patient

This paper deals with the recommendation of suitable diets to the diabetic patient for each meal times of the day, it considers three meal times of the day namely: Breakfast, Lunch and Dinner times and in each meal times several number of combinations of diets are considered as alternatives. The criterion taken for these diets are: sugar, cholesterol, carbohydrate and protein which are nutritional contents of those diets. The purpose of this paper is to develop an expert system to recommend specific diet to a diabetic patient according to the patient's blood sugar level in order to control the level of sugar for the patient.

The following datasets are taken from very well-known diabetics' meal planner from the Maharashtra state of India

Breakfast

- ✓ Egg white with capsicum and salad
- ✓ Paneerbhurji with plain roti
- ✓ Oat flakes + MilkEgg sandwich

Lunch

- ✓ Capsicum + dal with chapatti
- ✓ Cucumber + onion raita and mixed veg salad
- ✓ Chapati + chicken and salad

Dinner

- ✓ Chicken with chapatti and vegetable soup
- ✓ Phulka and curd
- ✓ Palak vegetable with chapatti and curd

3.2 Methodology used for analyzing problem

The first step while building an AHP model for a specific problem is to arrange its details in hierarchical structure as shown in figure below, level 0 shows objective of the analysis which is to recommend a suitable diet to a diabetic patient. The next level i.e. level 1 shows different criterions or attributes of diets which are Sugar, Cholesterol, Carbohydrate and Protein. The last level i.e. level 2 shows different types of diets for each meal time such as for Breakfast, for Lunch and for Dinner in which for each meal times different diet alternatives are considered. Here, patients' details are not considered as a criterion because by separating those from details of diets, analysis among them can be carried out easily.

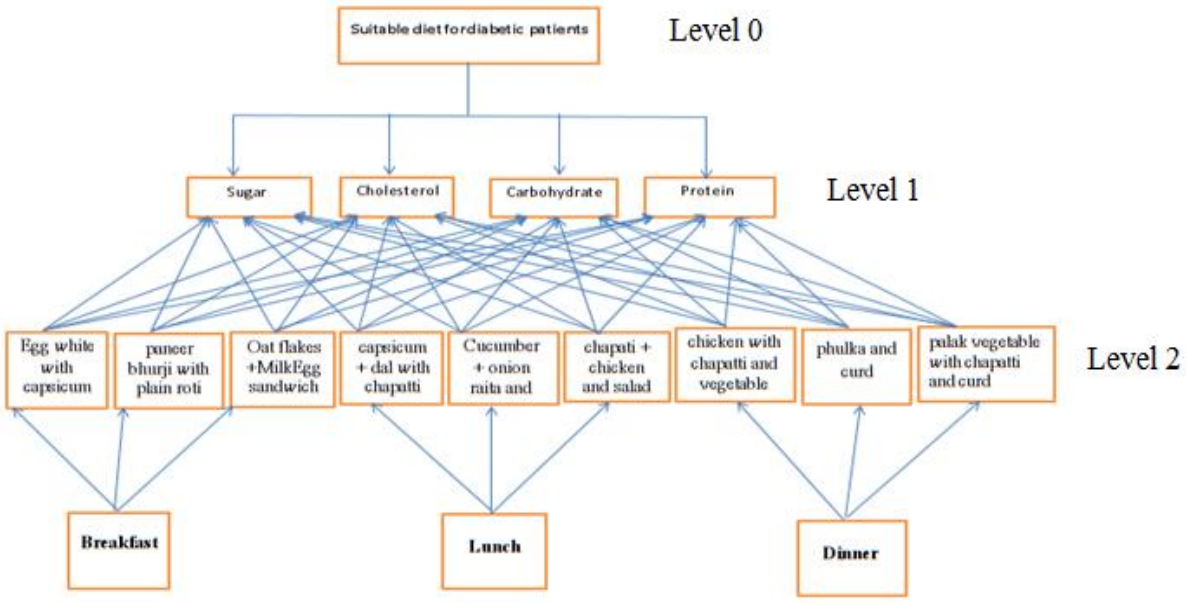

Fig.1: Hierarchical structure of proposed AHP model

3.3 Combination of Nutritional Values of the Diets

Since in each alternative there is several numbers of components, to create the criteria matrix and alternative matrix making the combination of the nutritional facts of those components is necessary.

Breakfast combination:-

Sugar -→

Alternative1 (A1) = 5.8g

Alternative2 (A2) = 5.8g

Alternative3 (A3) = 8g

Cholesterol -→ A1 = 0g

A2 = 0.035g

A3 = 0.16g

Carbohydrate -→ A1 = 9.7g

A2 = 23.5g

A3 =45.2g

Protein -→ A1 = 13g

A2 = 24g

A3 = 18.8g

Lunch combination:-

Sugar -→ A1 = 12.26g

A2 = 7g

A3 = 7.26g

Cholesterol -→ A1 = 0.001g

A2 = 0.003g

A3 = 0.12g

Carbohydrate -→ A1 = 80g

A2 = 24.9g

A3 = 23g

Protein -→ A1 = 26.34g

A2 = 8.8g

A3 = 40.34g

Dinner combination:-

Sugar -→ A1 = 2.7g

A2 = 4.96g

A3 = 5.66g

Cholesterol -→ A1 = 0.017g

A2 = 0.048g

A3 = 0.089g

Carbohydrate -→ A1 = 38.4g

A2 = 19.4g

A3 = 28.3g

Protein -→ A1 = 18g

A2 = 40.34g

A3 = 32.14g

3.4 Methodology for Criterion

The different parameters of AHP such as Eigen vector, Eigen value, consistency index and consistency ratios are calculated based on the following matrix table.

Table 4: Matrix for calculating weights of each criterion.

Criteria	Sugar	Carbohydrate	Cholesterol	Protein
Sugar	1	3	5	7
Carbohydrate	1/3	1	3	5
Cholesterol	1/5	1/3	1	3
Protein	1/7	1/5	1/3	1
Sum	**1.67**	**4.53**	**9.33**	**16**

After creating 4x4 matrixes for the criteria, the next step of AHP will be normalizing the criteria matrix which means dividing each element in every column by the sum of respective column. Then the calculation of weight/Eigen vector is done by taking the average of the sum of the rows of the normalized matrix. i.e. the weight of each criterion is as follows:

0.5586
0.2630
0.1217
0.0564

Weight of sugar = 55.86%(which is the most impactful criterion)
Weight of cholesterol = 26.30%
Weight of carbohydrate = 12.17%
Weight of protein = 5.64%

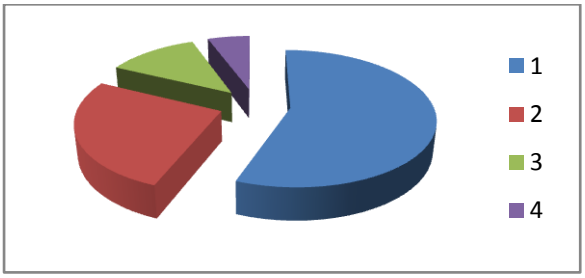

Fig.2 Pie chart for the representation of weights of the criteria.

Depending on the calculation and by looking at the output of the calculation we can decide that the most impact full criteria for the selection of the best alternative is sugar with the weight of 55.86%. Means that the alternative with having high amount of sugar value is recommended for the patient with low sugar blood glucose level and the alternative with low sugar amount is recommended for the patient with high blood glucose level.

Eigen value (λ_{max}) is calculated as multiplying the weight (Eigen vector) by the sum of each column and taking the total sum.

λ_{max} = (Column sum of 1st * weight of 1st column) + (Column sum of 2nd * weight of 2nd column) + (Column sum of3rd * weight of 3rd)+ (Column sum of 4th * weight of 4th column).

i.e.λ_{max} = (1.67*0.55)+(4.53*0.26)+(9.33*0.11)+ (16*0.05)

= 3.923

And then consistency index (CI) is calculated by the formula,

$CI = \lambda_{max} - n/n-1$

$= 3.923 - 4/4-1$

$= 0.02$

For n (size of the matrix) = 4 and RI = 0.90, which is obtained from Random consistency index table (Table 3)

The Consistency Ratio (CR) is calculated as

CR = CI / RI

= 0.02/0.9

= 0.0222

Consistency ratio (CR) = 2.22%, very consistent

The CR ratio must be under 10% so as to assume the chosen criterion as a good one. The obtained values of CR justify this condition.

3.5 Methodology for alternatives

In level 2 of the above diagram there will be one comparison matrix corresponds to pair wise comparisons between 3 alternatives with respect to each criteria. Thus, the comparison matrix of level 2 has size of 3 by 3 for each meal time.

Therefore the AHP process of the alternatives for the breakfast meal time based on the above analyzed nutritional facts will be as follows:

Table 5: Matrix for calculating weights of alternatives for breakfast meal time.

	A1	A2	A3
A1	1	3	5
A2	0.33	1	3
A3	0.2	0.33	1
Sum	**1.53**	**4.33**	**9**

After finding the normalized matrix of the above weight matrix the calculation of weight/Eigen vector is done by taking the average of the sum of the rows of the normalized matrix.

i.e. the weight of each alternative is as follows:

0.6339
0.2599
0.1060

Weight of A1 = 63.39%(the best alternative, which has low amount of sugar value)

Weight of A2 = 25.99%

Weight of A3 = 10.6%

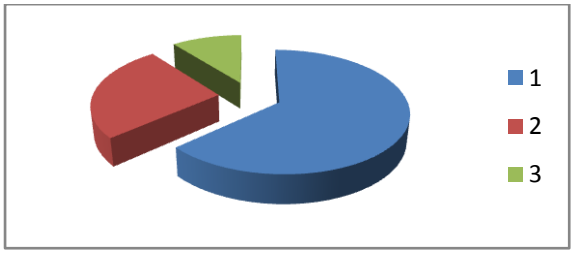

Fig.3 Pie chart for the representation of weights of alternatives for breakfast.

The next step of the AHP process is calculating Eigen value (λ_{max}), which is done by multiplying the sum of each column of the alternative matrix by the normalized matrix (weight) of the same alternative.

λ_{max} = (Column sum of 1st * weight of 1st column) + (Column sum of 2nd * weight of 2nd column) + (Column sum of3rd * weight of 3rd).

i.e. λ_{max}= (0.6336*1.53) + (0.2599*4.33) + (0.106*9)= 3.0487

Then consistency index (CI) is calculated by the formula,CI = λ_{max}– n/n-1

= 3.0487– 3/3-1

= 0.0243

The Consistency Ratio (CR) is calculated as

CR = CI / RI

= 0.0243/0.58, since n = 3 then RI = 0.58

= 0.04198

Consistency ratio (CR) = 4.198%, which is consistent.

In the same way, the Analytical Hierarchy Process (AHP) of Lunch and Dinner meal time will provide different result and different mapping.

4 RESULTS

4.1 Analysis of diabetic patient details and mapping

As the main objective of this paper is to recommend a particular diet that can surpass the blood sugar level of the diabetes in each meal time of the victim, the sample blood glucose level of the patient and the analyzed sugar level of the diets can be drawn and their result for the same is shown below in the graphs.The sample blood glucose level of different patients those are used for doing different types of practice by different researchers are given as below to be used for the mapping purpose of this research paper too. The measurement of the blood glucose level of the diabetic patient is mg/dl.

- Patient1 = 263mg/dl
- Patient2 = 210mg/dl
- Patient3 = 125mg/dl

And, the calculated weights of diets for breakfast are as given below:

- A1 = 0.6339
- A2 = 0.2599
- A3 = 0.1060

Therefore the mapping between the blood glucose level of the patient and the analyzed weight of the diabetic diet for breakfast meal time is shown as below:

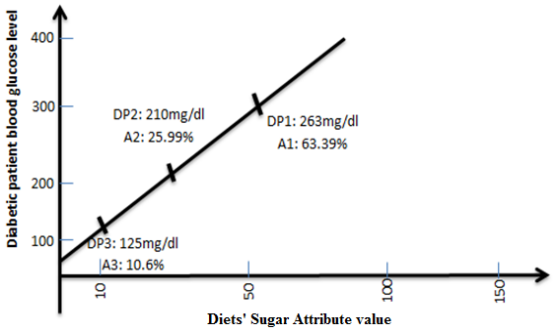

Fig.4 graph for representing the mapping between blood glucose levels and breakfast alternative.

4.2 Implementation

This stage comprises the real coding of the system which is writing of the visual basic commands that run the system. The codes were implemented and personalized in Visual basic programming language.

In the framework of the mealtime plan, age, gender, body mass index (BMI), blood Glucose levels (BGL), physical exercise and the connected diseases with the diabetic are the foremost threat issues to think through.

The scheme comprises of three main graphical user interface (GUI) apparatuses. The first constituent is the Patient form which entail of Id.No, name,

Address, gender, age, height, weight, physical activity type, blood glucose level (BGL) and supplementary diseases. The second is the diet/Food groups' form which contain of meal time, diets names and nutritional facts of the diet and favorite items list. The third one is the recommendation form which holds Id.No of the patient, meal time, BGL, weight, height and recommendation field. Fig.4, Fig.5 and Fig.6 gives sample screen shots of the user interface.

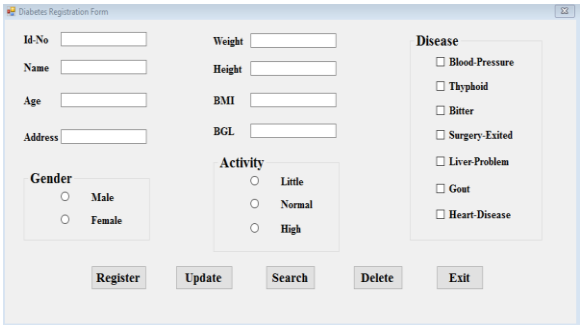

Fig. 5 Screenshot of diabetics registration form

Fig 5 is the application form which is used for the registration of diabetics to the database which stores the details of the patient and it contains the following data.

Idno	name	age	address	weight	height	BMI	BGL	gender	activity
107	Minte	20	Enate	65	1.70	67	110	Male	Normal
108	Tare	17	Cheha	60	1.65		100	Male	Medium

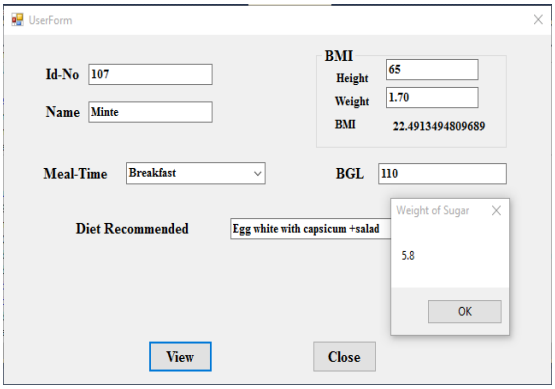

Fig. 6 Screenshot of diabetics user form

This form is intended for the user to access diabetic's diet according to their blood glucose level (BGL). The user have to choose meal time and fill the name and id-no textboxes, the body mass index (BMI) is calculated by the system when the user enters his/her weight and height. If the blood glucose level of the patient is high, the system will display diets having low sugar amount.

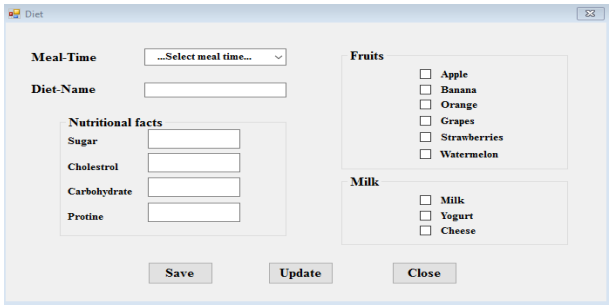

Fig. 7 Screenshot of diabetics diet form

Fig 7 this form is used for the registration of the diabetics' diet with their nutritional facts to make accessible for the user. And it contains the following sample data.

mealtime	name	sugar	cholestrol	carbohydrat	protien	fruits	milk
Breakfast	Egg white with	5.8	0	9.7	13	Apple	Yogurt
Breakfast	Paneer bhurji \	5.8	0.035	23.5	24	Apple	Yogurt
Breakfast	Oat flakes + Mi	8	0.16	45.2	18.8	Apple	Yogurt
Lunch	Capsicum + dal	12.6	0.001	80	26.3	Banana	Cheese
Lunch	Cucumber + or	7	0.003	24.9	8.8	Banana	Cheese
Lunch	Chapati + chick	7.26	0.12	23	40.34	Banana	Cheese
Dinner	Chicken with c	2.7	0.017	38.4	18	Grapes	Milk
Dinner	Phulka and cur	4.96	0.048	19.4	40.34	Grapes	Milk
Dinner	Palak vegetabl	5.66	0.089	28.3	32.14	Grapes	Milk

5. CONCLUSION

This research paper is designated for the recommendation of appropriate diet to the diabetic patients and implemented by using visual basic programming language for the recommendation of diabetic's diet through an expert system which envisioned to be used by the patient. The proposed expert system delivers the patients with medical instructions and rudimentary knowledge on diabetes diet. In fact, the accomplishment of the proposed expert system pass on through a number of phases such as problem identification and need identification, proposing appropriate solutions for the problem using different types of multi criteria decision making system and implementation.

The achieved outcomes of this research show that appropriate usage of AHP is used for the recommendation of proper diet to the diabetic patient that can control the blood sugar level of the patient. The attained outcomes by the method called AHP show that alternative one of the breakfast meal time is more appropriate to be taken by the patient who has high blood glucose level in his/her body whereas alternative two of lunch meal time is recommended for the patient with high

blood glucose level and the alternative one of dinner meal time is recommended to the patient who has a high blood glucose level.

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GOD, I always rely on you. THANK YOU!!!

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