Article 4

Selection of the Best Thermal Massage Treatment for Diabetes by using Fuzzy Analytical Hierarchy Process

Norpah Mahat, Syafiah Ahmad,
Faculty of Computer & Mathematical Sciences,
Universiti Teknologi MARA Perlis Branch, Malaysia

Abstract
Diabetes is a condition in which the human blood glucose (sugar) level is abnormally high due to the lack of insulin produced by the pancreas. As diabetes has been claimed to be a disease that is incurable, researchers have come out with numerous alternatives in making it curable and one of them is thermal massage treatment. This treatment refers to the application of chiropractic where it focuses on realigning the spine where diabetes is claimed to be related to the misalignment of thoracic 7 (T7). The objective of this study is to identify and select the best and most effective thermal massage treatment session(s) required for both T1D and T2D patients of different high glucose level in the blood to be reduced to the normal glucose level by using thermal massager. This study is conducted for the diabetic patients who receive treatments from Ceragem Healthcare Centre on how to optimise their thermal massage treatments to normalise their glucose level. Fuzzy Analytical Hierarchy Process (AHP) is utilised in this type of selection problem mainly due to the reliable results produced for the imprecise and uncertain preferences of the users in which able to be expressed as a fuzzy set (triangular fuzzy number). The findings indicated that the most significant criteria for effective thermal massage is determined by the "number of treatment session (per day)" where the best thermal massage treatment is derived from the normalised fuzzy weight of both criteria and sub-criteria.

Keywords: *Fuzzy Analytical Hierarchy Process, Diabetes, Thermal massage*

Introduction

Diabetes is defined as a condition in which the human blood glucose (sugar) level is abnormally high (Department of Human Services and Institute, 2013). Insulin; a hormone produced by the pancreas regulates human blood glucose level to maintain the normal level. In the case for Diabetes patient, the individual's blood glucose level is relatively high due to the failure of pancreas to produce insulin.

There are five types of diabetes which are; type 1 diabetes (T1D), type 2 diabetes (T2D), gestational diabetes, diabetes insipidus and pre-diabetes (Department of Human Services and Institute, 2013). However, this research will mainly focus on two types of diabetes which are T1D and T2D. T1D is also known as insulin dependent diabetes (Department of Human Services and Institute, 2013), where insulin is no longer produced by the pancreas due to the destruction of insulin β-cells (Bruni et al., 2014). T2D or non-insulin dependent diabetes (Department of Human Services and Institute, 2013) is a state where the insulin produced by the pancreas is in a small amount, in which inadequate to lower elevated blood glucose level.

Treatment for diabetes is focused on complications prevention because both T1D and T2D are incurable as claimed by the World Health Organisation and Department of Human Service and Institute in 2014 and 2013 respectively. Thus, researchers around the world provided a number of alternative treatments for both types of diabetes in order to find the cure. Chiropractic technique; a technique in which focuses on curing the misalignment of spines in diabetes

treatment is deemed to be one of the effective alternative treatments in addressing diabetes (Echeveste (2008), Sudano& Robinson (2011)). Essentially, the logic behind chiropractic technique is rooted in the nerve located in T7. This nerve acts as an information (impulse) transporter from the pancreas to the brain and vice versa. When there is a misalignment in T7, the nerve will be blocked from sending the information from pancreas to the brain in which hinder the insulin hormone to be produced by the pancreas.

Ceragem, a Korean company has applied chiropractic in its thermal bed massager, Ceragem Master V3 where the machine massages human spines and aligns any misalignments of the spines. This treatment had showed progressively positive result in reducing high blood glucose level of diabetic patients to the normal blood glucose level. In Malaysia, the Ceragem offers free trial treatments for their customers who seek treatments at their healthcare centres. Thus, this offer is an alternative for diabetes patients to reduce their cost of treatments.

The aim of this study is to identify and select the best and most effective thermal massage treatment session(s) required for both T1D and T2D patients of different high glucose level in blood to be reduced to the normal level in blood by using thermal massager.

Methodology

Past researches have shown that Fuzzy AHP is widely used for selection process such as selection of the diet meal while maintaining blood sugar level (Gaikwad et al., 2015). A model for diabetes treatment for T2D patients was introduced by Tadic et al. (2010) where they used fuzzy to develop the model.

Thus, Fuzzy AHP had been chosen to carry out the selection process where the data required for the study are derived from the opinions of the Directors of Ceragem on their decisions in selecting the best thermal massage treatment for diabetic patients, type T1D and T2D only. There are six criteria and twenty-two sub-criteria in which required to be studied in detailed for the selection process.

Fuzzy AHP required eight steps to be completed before the selection of the best thermal massage treatment for diabetes can be made. The eight steps are as follow:

Step 1: The hierarchy of the criteria and sub-criteria are constructed by decision maker as shown in Table 1.

Table 1: The hierarchy of criteria and sub-criteria

Selection of the best thermal massage treatment for diabetes					
Duration (minutes)	Temperature (°C)	Massage technique	Number of treatment session (per day)	Number of days for treatment session (per week)	Total number of treatment session
1-20	41-50	Automatic	1	1	1-100
21-30	51-60	Mode 1	2	3	101-200
40		Mode 4	>2	7	201-300
		Automatic&Mode 1			>300
		Automatic&Mode 4			
		Mode1&Mode4			
		Automatic,Mode1 ,Mode4			

Step 2: The comparison of the criteria or alternatives are made by decision maker by using triangular fuzzy numbers(TFN) of linguistic terms. Pair-wise contribution matrices of criteria and sub-criteria are formed by using TFN for each decision maker.

Step 3: Eq. 1 ($\widetilde{d}_{ij}$) is calculated when there is more than one decision maker after each decision maker's precedence ($\widetilde{d}_{ij}^{k}$) is averaged, where $\widetilde{d}_{ij}^{k}$ is the k^{th} preference of decision maker for i^{th} criterion via TFN.

$$\widetilde{d}_{ij} = \frac{\sum_{k=1}^{K} \widetilde{d}_{ij}^{k}}{K} \tag{1}$$

Step 4: Pair wise contribution matric is adjusted after precedence is averaged.

Step 5: The calculation of every criterion of geometric mean of fuzzy comparison values as cited in Ayhan, (2013), the triangular values are still represented by $\widetilde{r}_i$.

$$\widetilde{r}_i = \left(\prod_{j=1}^{n} \widetilde{d}_{ij} \right)^{1/n}, i = 1,2,..., n \tag{2}$$

Step 6: By using Eq. (3), the fuzzy weight for every criterion is calculated after the next three sub steps are implemented.

Step 6a: Vector summation is calculated for each $\widetilde{r}_i$.

Step 6b: The TFN is replaced in order to arrange it in increasing order after the (-1) power of summation vector is found.

Step 6c: Each $\widetilde{r}_i$ is multiplied with the reverse vector to find the criterion *i*'s fuzzy weight $(\widetilde{w}_i)$.

$$\begin{aligned} \widetilde{w}_i &= \widetilde{r}_i \oplus \left(\widetilde{r}_1 \oplus \widetilde{r}_2 \oplus ... \oplus \widetilde{r}_n\right)^{-1} \\ &= \left(lw_i, mw_i, uw_i\right) \end{aligned} \tag{3}$$

Step 7: The centre of area method as cited by Ayhan (2013) is applied to defuzzified $\widetilde{w}_i$ because they are still TFN. This calculation is conducted by applying Eq. 3.6.

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \tag{4}$$

Step 8: In Eq. (5), M_i is normalised although it is already a non-fuzzy number.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}$$

(5)

In order to normalise the weight of criteria and alternatives, all the eight steps are required to be performed. The result for multiplication of each weight of alternative with respective criteria is the score for each alternative. The highest score of alternative will be suggested to decision maker.

Results and Discussions

After performing all the steps of Fuzzy AHP, the criteria and sub-criteria had been ranked successfully. Table 2 shows the normalised relative weight and the ranks of the criteria.

Table 2: Normalised relative weight and the ranks of the criteria

Criteria	N_i	Ranks
Number of treatment session (per day)	0.317	1
Number of days for treatment session in a week	0.271	2
Total number of treatment session	0.235	3
Massage technique	0.106	4
Temperature	0.050	5
Duration	0.021	6

Based on the table above, a criterion of number of treatment session (per day) was at the first rank, followed by the number of days for treatment session in a week and the total number of treatment session. Consequently, the fourth, fifth and last ranks are massage technique, temperature and duration respectively. The ranks shown were based on the calculation of normalised relative weight, referring to the opinion from the Directors of Ceragem.

This postulates that the diabetic customers, type T1D and T2D, are advised to prioritise on the number of treatment sessions (per day), the number of days for treatment session in a week and the total number of treatment sessions in this order to reduce high blood glucose level to normal blood glucose level.

The sub-criteria were then ranked as shown in the Table 3 to take the highest prioritised criterion for the global importance weighting of the sub-criteria.

Table 3: The ranks of the global importance weightings

Sub-criteria	N_i	Ranks
3 times or more	0.251	1
7 days	0.214	2
301 times or more	0.159	3
201-300 times	0.053	4
2 times	0.048	5
Automatic mode, Mode 1 & Mode 4	0.046	6
51-60 (°C)	0.044	7
3 days	0.04	8

Mode 1 & Mode 4	0.023	9
1 time	0.018	10
1 day	0.017	11
40 minutes	0.016	12
Automatic mode & Mode 1	0.016	13
101-200 times	0.016	14
Automatic mode & Mode 4	0.011	15
1-100 times	0.007	16
41-50 (°C)	0.006	17
21-30 minutes	0.004	18
Mode 1	0.004	19
Automatic mode	0.003	20
Mode 4	0.003	21
1-20 minutes	0.001	22

Referring to the quantitative values in the table for the rank of global importance weightings of all criteria above, it is displayed that "3 times or more for number of treatment session (per day)" has the highest priority with the value of 0.251. "7 days" and "300 times or more" were at the second and third ranks with the values of 0.214 and 0.159 respectively. On the other hand, the sub-criteria for "massage technique", "temperature" and "duration" which were "Automatic Mode, Mode 1 & Mode 4", "51-60 °C" and "40 minutes" ranked sixth, seventh and twelfth with the values of global importance weight of 0.046, 0.044 and 0.016 respectively.

These values showed that the thermal massage for diabetes treatment, type T1D and T2D, is best to be done three times or more in a day and the effective thermal massage to treat diabetic customer is by undergoing the treatment every day until the total number of massage treatments exceeds three hundred times or more. In a nutshell, the best treatment for diabetic customer to reduce high blood glucose level to normal blood glucose level by using thermal massage is to receive the treatment three times or more every day until the total number of the treatment reaches three hundred times or more. Besides, the massage technique from the combination of automatic mode, mode 1 and mode 4 with the temperature of 51°C to 60°C and duration of 40 minutes per treatment session are deemed to be the most effective.

Conclusion

In this study, Fuzzy AHP method is used to select the best thermal massage treatment for diabetic customer at Courage Healthcare Centres in order to reduce high blood glucose level to normal blood glucose level. The selection of the best thermal massage treatment for diabetic customer is an uncertainty process due to the different level of high blood glucose and types of diabetes. This problem can be solved by using fuzzy number and linguistic variables to achieve higher accuracy and consistency results and outcomes.

In conclusion, based on the calculations of the normalised weight by using Fuzzy AHP method, the most important criteria in thermal massage treatment for diabetes,type T1D and T2D, is the "number of treatment session (s) (per day)" while its sub-criteria is "3 times or more". This indicates that it is the most important for the diabetic customer to receive thermal massage treatment three times or more in a day. Besides, the best thermal massage treatment for diabetic customer to reduce high blood glucose level to normal blood glucose level is by having three times or more treatment a day until the total number of treatment exceeds three hundred times. The treatment is also encouraged to be from the combination of Automatic Mode, Mode 1 and Mode 4 for 40 minutes per treatment session with temperature of 51°C to 60°C.

Acknowledgments
The authors would like to express our gratitude to Marketing Director of Ceragem Malaysia SdnBhd, Director of Ceragem branch Sungai Petani and Director of Ceragem branch Alor Setar for their opinions and willingness to share information on thermal massage treatment for diabetes.

References

Ayhan, M. B. (2013). A Fuzzy AHP approach for supplier selection problem: A case study in a gearmotor company. *International Journal of Managing Value and Supply Chains, 4*(3), 11-23.

Bruni, A., Gala-Lopez, B., Pepper, A. R., Abualhassan, N. S., & James Shapiro, A. M. (2014). Islet cell transplantation for the treatment of type 1 diabetes: Recent advances and future challenges. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 7*, 211–223.

Department of Human Services,& Institute. (2013). *Diabetes*. Retrieved November 1, 2016 from https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/diabetes

Echeveste, A. (2008). Chiropractic care in a nine year old female with vertebral subluxations, diabetes & hypothyroidism.*Journal of Vertebral Subluxation Research (JVSR),* 1-5.

Gaikwad, S. M., Mualy, Dr. P., &Joshi,R. R. (2015). Analytical Hierarchy Process to recommend an ice cream to t a diabetic patient based on sugar content in it. *Procedia Computer Science, 50, 64-72.*

Sudano, N., & Robinson-LeBlanc, D. (2011). Improved A1 C levels in a patient with insulin-dependent type I diabetes undergoing chiropractic care : A case report. *J. Pediatric, Maternal & Family Health*, (4), 120-124.

Tadic, D., Popovic, P. &Dukic, A. (2010).A Fuzzy approach to evaluation and management of therapeutic procedure in diabetes mellitus treatment.*Yugoslav Journal of Operations Research, 20(1), 99-116.*

World Health Organization (2016).*Global report on diabetes*. Retrieved October 30, 2016 from http://www.who.int/diabetes/publications/grd-2016/en/