EVALUATION OF HEALTH RELATED QUALITY OF LIFE INDICATORS USING RANKING FUZZY NUMBER

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ABSTRACT

Health-Related Quality of Life (HRQoL) is one of the significant current discussions in health fraternity. HRQoL encompasses multidimensional indicators and serves the purpose of evaluating health quality among patients or people with health-related problems. It evaluates patients' perceptions of the impact of disease and treatment on their indicators such as physical, psychological, social function and well being. However there is no clear suggestion of which indicators contributed more than other. Various approaches have been proposed in evaluating of HRQoL and most cases have relied heavily on statistical techniques. The arbitrary nature of HRQoL paves the way for an alternative perspective in its evaluation approaches. This paper proposes a ranking of HRQoL indicators using a method of ranking fuzzy numbers. One hundred and fifty elderly respondents from Terengganu State of Malaysia were sampled to elicit information regarding their health related status over the eight indicators using a questionnaire. Respondents were asked to rate their regularity of experiencing health-related problems in a Likert-type scale of five. Data of the eight indicators were normalized into triangular fuzzy numbers. The method for ranking of triangular fuzzy numbers based on the left and the right spreads at some *r*-levels of triangular fuzzy numbers is employed. Data were computed using a computer algebra system to obtain magnitude for each indicator. It is shown that the indicator of emotion has recorded the lowest problematic level while the indicator of bodily pain recorded the highest problematic level experienced by elderly people. The ranking signifies the impact of the indicators to health quality specifically among elderly people.

Keywords: *Health Related Quality of Life, Fuzzy Sets, Fuzzy Numbers, Health Indicators*

1. INTRODUCTION

One of the most significant current discussions in modern living is the status of quality of life (QoL). The conceptual definitions of QoL are indeed varies depending on social status and local preferences. Some of the definitions of QoL are extended specifically to health related issues and refers as health related quality of life (HRQoL). There are two types HRQoL which are generic or specific [1]. Generic HRQoL measures the QoL of well-being generally, while specific HRQoL measures by specific condition or disease of the well-being. Occasionally, QOL and HRQoL are often used interchangeably with little distinction between the two concepts. But a loose distinction between these two concepts can be drawn by giving more emphasis on health related rather than the general outlook of quality in human lives. HRQOL is defined as a multidimensional concept that reflects a person's perception of their physical, psychological, and social function and health status [2], [3]. HRQoL is also variously referred as patient-assisted outcome measure, health status, and functional status or just as outcome measure. Sharma [4] defines HRQoL is a multidimensional dynamic concept that has developed from the need to estimate the impact of diseases, which includes economic welfare, characteristic of community and environment, and health status. Most of the conceptual definitions of HRQoL refer to a person or group's perceived their physical and mental health.

There are many thoughts and notes about what is HRQoL and how it being measured. Mc Call [5] postulates measure of HRQoL was the extent to which people's happiness requirements are met. Some relate measures of HRQoL with their defined indicators. It comprises the indicators of ability, adaptation, appreciation, basic needs, belonging, control, demands and responsibilities, enjoyment, happiness, needs, knowledge, as far as pleasure and politics. The intangible and subjective definitions of HRQoL imply the need to embark to a subjective evaluation. Broad and arbitrary definitions of HRQoL motivate a new approach to its measurement. Each indicator contributes to one's overall assessment of HRQoL. Perhaps the key indicators of HRQoL may include physical functions, sensations, self-care, cognition pain/discomfort and emotional/psychological well-being. Understanding HRQoL in today environment is particularly important in health care where monetary or material measures are temporarily excluded. Decision on human future activities is closely related to their effects on HRQoL. Thus concept of HRQoL is used as an important parameter for measuring outcome in modern medicine. This can be used as discriminative as well as an evaluative indicator.

Nowadays, there is a growing field of research concerned with developing, evaluating and applying HRQoL measures within health related research. Many of these focus on the measurement of HRQoL rather than a more global conceptualization of QoL. Most of these researches measure HRQoL from the perspective of the patient and thus take the form of self completed questionnaires. For example, [6] conducted a study to compare generic HRQoL across ten chronic disease clusters and 33 disease categories/severities from the perspectives of patients and parents. The analysis were based on over 2,500 pediatric patients from 10 physician-diagnosed disease clusters and 33 disease categories/severities over 9,500 healthy children utilizing the PedsQL^{TM} 4.0 Generic Core Scales. The Generic Score Scale also used by Hill *et al.* [7] to demonstrate the value of categorical confirmatory factor analysis and Item Response Theory in examining a HRQoL in children and adolescents. Researches in HRQoL were varied in approaches and studied across genders, age groups and type of diseases. For example, Barr *et al.* [8] conducted a research of HRQoL in children to determine if HRQoL is affected in children with velopharyngeal insufficiency by using statistical analysis such as means, standard deviations and covariance. Wong *et al.* [9] conducted a research on visual impairment and its impact on HRQoL among adolescents. They used descriptive statistics measures such as means, standard deviations, confidence interval, and P-value to describe results.

Meanwhile one of the age group that vulnerable to health related problems are elderly people. Among health care staff, it is commonly believed that old people in general have a poor state of health and a poor social situation. This view is probably reflected by the fact that health care staffs are mainly confronted with sick elderly people. Unquestionably, old age has been regarded as tantamount to poor health. Many researches have been conducted to study health related among elderly people. For instances, a research to show the effects of HRQoL among elderly people was conducted by Cavlak *et al.* [10]. They studied the effects of musculoskeletal pain on HRQoL and to look at gender differences in this field among elderly people living in Turkey. Data were collected via face-to-face interview and analyzed statistically. Chia *et al.* [11] assessed the impact of visual impairment on HRQOL in an older population and compares it with the impact of major medical conditions. There was also a study conducted by Rueda and Artazcos [12] to analyses gender inequalities in health among elderly people in Spain. They adopted a conceptual framework that globally considers three dimensions of health determinants: socio-economic position, family characteristics and social support. Multiple logistic regression models were applied to separate analyses between genders. Relationships between elder people and income were studied by Huguet *et al.* [13]. They assessed the independent effect of income on HRQL among older adults in Canada and the United States. HRQL was measured with the multidimensional Health Utilities Index Mark 3. A simple linear correlation analysis was employed to explain relationship between HRQL and income in the elderly population.

Although research on HRQoL has increased of late, many researches are assessed and measured using statistical approaches and qualitative nature such as interviews and observations. Despite these works, little is known about weights or importance levels of indicators that constituted HRQoL. It is a fact that there are many indicators surround human beings that will affect their quality of life. Physical pains, mental depressions, emotional disturbance are among the indicators prescribed in literatures of HRQoL. The present research takes a different move to prioritize the indicators in HRQoL with a different approach. Notwithstanding the importance of statistical techniques, this research evaluates HRQoL in tandem with the arbitrary, vague and uncertain definitions of HRQoL. Against this background, the purpose of this paper is to rank the eight indicators of HRQoL using ranking fuzzy numbers among elderly people. In other words, the theory of fuzzy sets is utilized to describe perception of elderly people toward HRQoL indicators. The applications of fuzzy sets in health sciences and wellbeing are not something new. For example, the theory has been applied in medical decision making [14],[15],[16] and also in measuring quality of life [17], [18]. The preliminary concept of fuzzy numbers, ranking fuzzy numbers and how it was developed are elucidated in the next sections.

2. FUZZY NUMBERS AND RANKING FUZZY NUMBERS

The concept of fuzzy numbers arises from the fact that many quantifiable phenomena do not provide themselves to being characterized in terms of absolutely precise numbers. In this paper, fuzzy number can be defined as follows

Definition 1 A fuzzy number is a fuzzy set like $u : \Re \to I = [0,1]$ which satisfies:

1. u is upper semi-continuous.
2. $u(x) = 0$ outside some interval $[a, d]$,
3. There are real numbers a, b such that

   $a \le b \le c \le d$ and

   a. $u(x)$ is monotonic increasing on $[a, b]$,

b. $u(x)$ is monotonic decreasing on $[c,d]$,

c. $u(x)=1,\ b\le x\le c$.

The membership function u can be expressed as where $u_L:[a,b]\to[0,1]$ and $u_R:[c,d]\to[0,1]$ are left and right membership functions of fuzzy number u. $\Re$ stands for the set of all real numbers, E stands the set of fuzzy numbers, u expresses a fuzzy number and $u(x)$ for its membership function, $\forall x\in\Re$ [19].

An equivalent parametric form is also given in [20] as follows:

Definition 2 A fuzzy number u in parametric form is a pair $(\underline{u},\bar{u})$ of functions $\underline{u}(r),\bar{u}(r),\ 0\le r\le 1$, which satisfy the following requirements:

1. $\underline{u}(r)$ is a bounded monotonic increasing left continuous function,
2. $\bar{u}(r)$ is a bounded monotonic decreasing left continuous function,
3. $\underline{u}(r)\le\bar{u}(r),\ 0\le r\le 1$.

The trapezoidal fuzzy number $u=(x_0,y_0,\sigma,\beta)$, with two defuzzifier x_0,y_0, and left fuzziness $\sigma>0$ and right fuzziness $\beta>0$ is a fuzzy set where the membership function is as

$$u(x)=\begin{cases}\dfrac{1}{\sigma}(x-x_0+\sigma), & x_0-\sigma\le x\le x_0,\\ 1, & x\in[x_0,y_0],\\ \dfrac{1}{\beta}(y_0-x+\beta), & y_0\le x\le y_0+\beta,\\ 0, & otherwise.\end{cases}$$

and its parametric form is

$$\underline{u}(r)=x_0-\sigma+\sigma r,\quad \bar{u}(r)=y_0+\beta-\beta r$$

Provided that, $x_0=y_0$ then u is a triangular fuzzy number, and rewrite $u=(x_0,\sigma,\beta)$. The support of fuzzy number u is defined as follows:

$$\sup(u)=\overline{\{x|u(x)>0\}},$$

where $\overline{\{x|u(x)>0\}}$ is closure of set $\{x|u(x)>0\}$.

The concept of fuzzy numbers has been developed in many decision making problems. Ranking fuzzy numbers is one the methods that conceptualize fuzzy numbers to describe preference or rank. It plays very important role in linguistic decision making and some other fuzzy application systems. Development of ranking fuzzy numbers started when Dubois and Prade [21] introduced concepts of fuzzy numbers. Since then, many researches proposed the related methods or applications for ranking fuzzy numbers. For instance, Bortolan and Degani [22] reviewed some methods to rank fuzzy numbers. Chen and Hwang [23] proposed fuzzy multiple attribute decision making. Choobineh and Li [24] proposed and index for ordering fuzzy numbers. Dias [25] ranked alternatives by ordering fuzzy numbers while Lee *et al.* [26] ranked fuzzy numbers with a satisfaction function. Requena *et al.* [27] utilized artificial neural networks for the automatic ranking of fuzzy numbers, However, Chu and Tsao [28] argued that some of these above methods are difficult to implement on grounds of computational complexity and others are counterintuitive or not discriminating enough. Moreover, Wang and Lee [29] pointed out that many methods have different outcomes on the same problem. Thus, they proposed a method of ranking fuzzy numbers with an area between the centroid and original points. However, Asady and Zendehnem [30] discovered other problems in Wang and Lee method's. Thus, they proposed a revision of 'ranking fuzzy numbers with an area between the centroid and original point' to improve the Wang and Lee method. This method has some drawbacks, i.e., for all triangular fuzzy numbers $u=(x_0,\sigma,\beta)$ where $x_0=\dfrac{\sigma-\beta}{4}$ and also trapezoidal fuzzy numbers $u=(x_0,y_0,\sigma,\beta)$, such

that $x_0 + y_0 = \frac{\sigma - \beta}{2}$, gives the same results. Therefore, Abbasbandy and Hajjari [31] proposed a new approach for ranking of trapezoidal fuzzy numbers based on the left and the right spreads at some r -levels of trapezoidal fuzzy numbers. The calculation of the proposed method is relatively straight forward. The definition that lead to the approach and formulation of ranking are explained as follows.

Definition 3 Magnitude of Trapezoidal Fuzzy Numbers.

For an arbitrary trapezoidal fuzzy number $u = (x_0, y_0, \sigma, \beta)$, with parametric form $u = (\underline{u}(r), \bar{u}(r))$, the magnitude of the trapezoidal fuzzy number u is defined as;

$$Mag(u) = \frac{1}{2}\left(\int_0^1 (\underline{u}(r) + \bar{u}(r) + x_0 + y_0) f(r) dr \right),$$

where the function $f(r)$ is an non-negative and increasing function on [0,1] with $f(0) = 0$, $f(1) = 1$, and $\int_0^1 f(r)dr = \frac{1}{2}$. Obviously, function $f(r)$ can be considered as a weighting function.

In this paper, $f(r) = r$ is chosen. Obviously, the magnitude of a trapezoidal fuzzy number u, which is defined by Definition 3 synthetically reflects the information on every membership degree and meaning of magnitude is visual and natural. The resulting scalar value is used to rank the fuzzy numbers. In the other words, $Mag(u)$ is used to rank fuzzy numbers. The larger $Mag(u)$, the larger fuzzy number. Therefore, for any two trapezoidal fuzzy numbers u and $v \in E$, the ranking of u and v defined by $Mag(.)$ on E as follows:

$Mag(u) > Mag(v)$ if and only if $u \succ v$,

$Mag(u) < Mag(v)$ if and only if $u \prec v$,

$Mag(u) = Mag(v)$ if and only if $u \sim v$.

The definitions of fuzzy numbers and ranking fuzzy numbers are utilized in the computations of the following experiment.

3. AN EXPERIMENT

An experiment was conducted to elicit perception of 150 elderly people at the State of Terengganu, Malaysia. Respondents were randomly selected to answer a simple questionnaire of HRQoL. The questionnaire was constructed by authors based on literatures in HRQoL and also a questionnaire proposed by [7]. There were eight indicators of HRQoL in the questionnaire and the respondents need to respond about the level of experiencing health related problem with respect to the eight health related indicators. The eight indicators are given as follows and being assigned in alphabetical order as to facilitate computing processes.

Physical (A), Role-physical(B), Bodily pain (C), Vitality (D),
Social (E), Emotional (F), Role-emotional (G), Workplace (H).

All the eight indicators become the main item of questionnaire and respondents need to respond in scale from 1 to 5 to indicate their experience over health related symptoms. Scale 1 represents never has a problem, 2 represents almost never has a problem, 3 represents often has a problem, 4 for sometime has a problem and 5 for almost always has a problem. Respondents were a group elderly people aged 58-70 years old. For the computational purposes, triangular fuzzy numbers (TFNs) were also defined for the eight indicators to handle the fuzziness of perceptions. Below is an example how the eight indicators were evaluated.

4. IMPLEMENTATION

The method proposed by Abbasbandy and Hajjari [31] is utilised as a basis in these computations. However this paper has made little contributions to the method. Trapezoidal fuzzy number in the original method are replaced with triangular fuzzy number by applying the condition c=b (see Definition 1). This paper also introduces a three-step algorithm to facilitate computations. For the purpose of clarity in implementing the computation, Physical Indicator (A) is used as an example. Computations are executed according to the following steps.

Step 1: Define TFN
Scales of responses are defined in TFNs.
1 = TFN (1, 1, 2), 2 = TFN (1, 2, 3), 3 = TFN (2, 3, 4), 4 = TFN (3, 4, 5), 5 = TFN (4, 5, 5).

Step 2: Average Weight Score
Responses from 150 respondents are then averaged using arithmetic mean to obtain average weight score. The score is

$$= [(1,1,2)\otimes 33 \oplus (1,2,3)\otimes 45 \oplus (2,3,4)\otimes 23 \oplus (3,4,5)\otimes 37 \oplus (4,5,5)\otimes 12] \div 150$$

= (2.55, 2.67, 3.59).
So, the average weight score for Physical aspect (A) is (2.55, 2.67, 3.59).

Step 3: Magnitude of TFN
With reference to the Definition 3, magnitude of Physical Indicator (A) is computed using the computer algebra system, MAPLE. The magnitude for indicator A is given as

Mag (A) = 2.6267

The magnitudes for other indicators are computed in the same manner.

Finally, the indicators are ranked in ascending order based on their magnitudes.

The average weight score for all indicators of HRQoL can be summarized in Table 1.

Table 1 The arithmetic mean score in triangular fuzzy numbers for each indicator.

HRQoL Indicators	Mean Weight Score, TFNs
Physical (A)	(2.55, 2.67, 3.59)
Role-physical (B)	(2.27, 3.21, 4.04)
Bodily pain ©	(2.60, 3.47, 4.09)
Vitality (D)	(1.95, 2.69, 3.57)
Social (E)	(2.48, 3.35, 4.17)
Emotional(F)	(1.95, 2.69, 3.54)
Role-emotional (G)	(1.96, 2.69, 3.59)
Workplace (H)	(2.33. 3.20, 3.99)

The magnitudes and ranking of the eight indicators are presented in Table 2.

Table 2: Magnitudes of Indicators and Ranking

HRQoL Indicators	Magnitude	Ranking
Physical (A)	2.6267	7
Role-physical (B)	2.3391	4
Bodily pain (C)	2.6517	8
Vitality (D)	2.0233	2
Social (E)	2.5483	6
Emotional(F)	2.0208	1
Role-emotional (G)	2.0350	3
Workplace (H)	2.3950	5

Based on the magnitudes, ranking of the HRQoL are obtained as F $\prec$ D $\prec$ G $\prec$ B $\prec$ H $\prec$ E $\prec$ A $\prec$ C where the symbol $\prec$ represents 'has less problem than'. Emotional was the least problematic indicator among elderly people. On the other extreme, bodily pain was the most problematic indicator experienced by respondents. Not to mention the significance of other indicators, the results really show the physical aspects of elderly person may need extra attentions among medical fraternity and health conscious members.

5. CONCLUSION

Imprecise definitions of HRQoL pave the way to an alternative method in its evaluation. This paper has presented one method of many fuzzy approaches in health-related evaluation. In this experiment, levels of problematic experienced by elderly people were evaluated against the eights indicators of the defined health related quality of life. The triangular fuzzy numbers have been introduced in defining the problematic levels. Ranking of the indicators has been established by the indicated magnitudes. The functions which consider the flexibility of fuzzy numbers were generating the magnitude. Emotional indicator was the least problematic indicator while bodily pain

was ranked as the most problematic indicator among elderly person. The results offer a good reflection on the level of problematic pains suffered by elderly person..

6. REFERENCES

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