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Efficient Management Design for Swimming Exercise Treatment

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Exercise-mediated physical treatment has attracted much recent interest. In particular, swimming is a representative exercise treatment method recommended for patients experiencing muscular and cardiovascular diseases. The present study sought to design a swimming-based exercise treatment management system. A survey questionnaire was completed by participants to assess the prevalence of muscular and cardiovascular diseases among adult males and females participating in swimming programs at sport centers in metropolitan regions of country. Using the Fuzzy Analytic Hierarchy Process (AHP) technique, weighted values of indices were determined, to maximize participant clarity. A patient management system model was devised using information technology. The favorable results are evidence of the validity of this approach. Additionally, the swimming-based exercise management system can be supplemented together with analyses of weighted values considering connectivity between established indices.

Key Words: Swimming exercise treatment, Fuzzy, AHP, Fuzzy AHP

INTRODUCTION

Medical and technological advances are extending the lifespan of humans, and are leading to increased individual health and by decreased mortality of the elderly in Korea (Ministry of Health & Welfare, 2007).

Increase of body fat and reduction of sarcopenia that occur upon aging influence deterioration of physical function and the prevalence of metabolic and degenerative diseases (Beaufrere and Morio, 2000). Thus, aging is associated with appearance and increasing prevalence of various health problems and physical limitations. With this increasing infirmity, physical exercise becomes more difficult and the heart and blood vessel diseases become more common with deteriorations in cardiopulmonary function and immunity ability (Yang, 2002).

In the elderly, water-based exercise has been recommended in the recuperation form ailments and as to prevent the onset of disease (Stamford et al., 1998). Swimming makes more fundamental treatments possible because of the resulting improvements of circulatory organs and metabolic systems (Ruoti et al., 1994; Long et al., 1996). Exercises performed in water contribute to improved aerobics capacity and physical flexibility by significantly reducing impacts and muscular stresses (Buskirk, 1985). Moreover, as the exercises are often conducted as part of a group, the companionship can relieve melancholia and restore confidence (Basmajian, 1987). Water-based exercise is useful for all ages from childhood to old age, and is effective for uniform body growth and mental acumen. As well, it is very useful as a recuperative exercise to restore muscle strength, since the buoyancy of the medium reduces impact-related stress while offering resistance. Since the exercises are typically done in municipal facilities, they can be an inexpensive and readily available means of physical therapy (Kang et al., 2003).

In one study, female seniors >60-years-of-age who participated in a 12-week water exercise program experienced a reduction in body fats, triglyceride (TG) and increased high density lipoprotein-cholesterol (HDL-C) (Kim, 2008). Improvements in cardiopulmonary function and physical strength during a 12-week water exercise program among 50-year-old participants with coronary artery diseases (Kang et al., 2003).

Despite these positive experiences, water-based exercise should be individually tailored considering a person's physical capability. Relatively little attention has been paid to this area. Presently, an exercise treatment management system that can be modified to an individual's needs was designed. Firstly, sensations felt by participants during

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ABBREVIATIONS: AHP, Analytic Hierarchy Process; TG, triglyceride; HDL-C, high density lipoprotein-cholesterol; SCL, symptom check list; HSCL, hopkins symptom check list; BSI, brief symptom inventory; CR, consistency ratio; USN, ubiquitous sensor network; XML, extensive markup language; SCM, supply chain management.

swimming were indexed and weighted values and priority ranking for these indices was analyzed. In addition, using the same index, we tried to model a system to systematically manage patients based on different priority rankings; that is, we tried to model a system that provided patients with optimized exercise therapy. The modeling was done in real-time based on a dispersion environment system, an information technology (IT) of exercise management therapy. Due to the varying characteristics of swimming exercises and the small number of therapists who are often responsible for a much larger number of patients simultaneously, individual patient characteristics may be overlooked. The presently-designed system is advantageous in this regard, since it allows real-time checking of the priority rankings of factors affecting the various processes of swimming-based exercise treatment.

METHODS

Subjects

The subjects were 52 adult men and women people diagnosed muscular system and/or cardiovascular system diseases and 23 healthy adults who were participating in swimming programs at sport centers in metropolitan regions in Korea (Table 1, 2).

Detailed status with regard to object people of the questionnaires is like (Table 1) and (Table 2).

Research method

As a survey tool, questionnaires were used to gauge the impacts of swimming on mental health; relevant survey tools were the Symptom Check List (SCL-90; Derogatis et al., 1973), Hopkins Symptom Check List (HSCL) and Symptom Check List-90-Revised (SCL-90-R). The brief symptom inventory (BSI) re-standardized by Kim and Won (1984) were used to appropriately re-standardize the survey for the present use. As a tool for measuring psychological, physical, environmental, and social satisfaction through swimming, questionnaires developed by Ragheb and Beard

Table 2. Age characteristics of study participants

Age (years)	People with experiences of muscular diseases	People with experiences of cardiovascular diseases	Total
20+	2	0	2
31~39	4	2	6
40~49	19	6	25
50~59	23	11	34
60+	4	2	6
Total	52	21	73

Table 1. Subject characteristics based on questionnaire responses

	People with experiences of muscular diseases	People with experiences of cardiovascular diseases	Other*	Total
C sport center located in Seoul city	19	7	11	37
T sport center located in Suwon city	16	6	8	30
J sport center located in Incheon city	17	8	4	29
Total	52	21	23	96

*Healthy adults or those who were infirmed but not experiencing muscular system and/or cardiovascular diseases.

Table 3. Indices for treatment management of swimming exercises

Items	Indices	Explanation
Psychological factors	Interests	Swimming program is very interesting
	Psychological confidence	Swimming program provides me with confidence.
	Emotional stability	Swimming program gives me emotional stability.
Physical factors	Test for physical capability	I can test my physical capability through the swimming program I am taking.
	Solve stresses	It helps in relieving stress.
	Improvement of physical strength	Physical strength can be improved.
	Restore physical vitality	It restores physical vitality.
Environmental factors	Cleanness of facilities and equipment	Exercise facilities and places are clean and fresh.
	Modernization of facilities and equipment	Exercise facilities and equipments must be modern.
	Interior of facilities and equipment	Exercise facilities and places are well-prepared.
Social factors	Relationship with therapists	Relationship with therapists instructing swimming programs.
	Relationship with peers	Relationship with other peers participating in swimming programs.
	Consideration for other people	Swimming programs help to understand other people.
Mental health factors	Symptom of physical constitution	Symptoms appear periodically due toabnormalities of physical function.
	Symptom of melancholia	Decreased motivation and vitality, and increased depression.
	Symptom of anxiety	Physical symptoms related to uncertainties such as anxiety, nervousness, and excessive sensibility.

(1980) and modified by Kim (1997) and Lee (1992) were used.

Establishment of indices

Prior research data concerning impacts of swimming on patients were analyzed and, based on this data, indices were rearranged (Table 3) to design the swimming-based exercise management system.

Analyses of weighted values using Fuzzy Analytic Hierarchy Process (AHP) technique

AHP is a decision-making technique (Saaty, 1980) that can elucidate the optimum alternative by arranging issues of decision-making with a hierarchical structure. It is widely-recognized as a sturdy but flexible, multiple standard decision-making tool capable of handling complex issues of decision-making (Saaty, 1980; Elkarmi and Mustafa, 1993). In this research, fuzzy theory (Zadeh, 1965) was added to AHP technique for attempting to minimize selection absurdities upon completion of the questionnaire. Fuzzy theory was posited to mathematically explain the phenomena of unclear quantitative information, inaccuracies and ill-logic of human thinking and judgments. Existing logic system is a general set composed of logic system (0, 1) of either 0 or 1. But fuzzy set is a concept of multiple logics system [0, 1] defined in limitless values of many instead one object is expressed in one value (Zadeh, 1978). Fuzzy AHP is a decision-making technique for drawing out the relative level of importance of evaluation standards or alternatives by handling results of relative comparisons as fuzzy numbers for handling unclear and absurd uncertainty inherent to human judgment in processes of comparative comparison. Presently, the Extent Analysis Method on Fuzzy AHP (Chang, 1996), which is one method for handling fuzzy numbers in the process of AHP analyses, was applied.

If we assume that fuzzy comparative comparison matrix A is:

$$A=[a_{ij}]=[(l_{ij}, m_{ij}, u_{ij})], (i,j=1,2,\cdots,n) = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}$$

All $a_{ij}=(1,1,1)$ for $i=j$ and relationship of $l_{ij}=\frac{1}{l_{ij}}$, $m_{ij}=\frac{1}{m_{ij}}$, and $u_{ij}=\frac{1}{u_{ij}}$ are established and fuzzy AHP application procedure of Chang is:

1 phase, if Fuzzy Synthetic Extent value of its element is called as Ei, it can be defined as follows:

$$E_i=\sum_{j=1}^{n} a_{ij} \otimes \left(\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}\right)^{-1} \quad \text{Equation (1)}$$

2 phase, degree of possibility to be $M_2 \geq M_1$ with regard to triangular fuzzy number $M_1=(l_1, m_1, u_1)$, $M_2=(l_2, m_2, u_2)$ can be defined as follow.

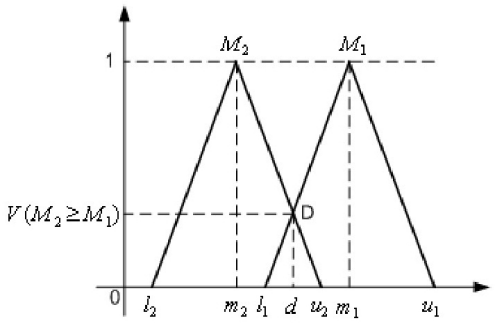

Fig. 1. Intersection of M1 and M2.

$$\begin{pmatrix} V(M_2 \geq M_1)=hgt(M_2 \cap M_1)=\mu_{M_2}(d) \\ 1, \quad \text{if } m_2 \geq m_1 \\ 0, \quad \text{if } l_1 \geq u_2 \\ \dfrac{l_1-u_2}{(m_2-u_2)-(m_1-u_1)}, \quad otherwise \end{pmatrix} \quad \text{Equation (2)}$$

In here, d means x coordinates value of crossing points of u_{M_1} and u_{M_2} (Fig. 1).

3 phase, degree of possibility that triangular fuzzy number M can be bigger than other k number of fuzzy numbers of $M_i=(i=1,2,\cdots,n)$ can be defined as follow.

$$\begin{aligned} V(M \geq M_1, M_2, \cdots, M_k) &= V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and} \cdots \text{ and } (M \geq M_k)] \\ &= \min V(M \geq M_i), i=1,2,\cdots,k, \end{aligned}$$

Equation (3)

4 phase, with regard to specific element i(i=1, 2, ⋯, n), if we assume as $w'=\min V(E_i \geq E_j), (j=1,2,\cdots,n; i \neq j)$, then weighted value vector of each element is as follow.

$$W'=(w'_1, w'_2, \cdots, w'_n)^T \quad \text{Equation (4)}$$

And, we can obtain regularized weighted value vector W of each element as below if we regularize this.

$$W=(w_1, w_2, \cdots, w_n)^T \quad \text{Equation (5)}$$

In this research, the relative level of importance was compared by enumerating the uncertainty inherent in human judgment in the process of comparative comparison by applying a previously described algorithm (Chang, 2007).

RESULTS

Analyzed specimens

Weighted values and priority rankings of factors influencing swimming-based exercise treatment were analyzed using Fuzzy theory-AHP. In order to ascertain whether weighted values acquired through comparative comparison maintained logical consistency or not, the consistency ratio (CR) was calculated. If CR is <0.1, it is evaluated as reasonable and a CR <0.2 indicates that it has consistency at the level enabling accommodation. Weighted values and priority

Table 4. Weighted value between factors influencing exercise treatment and priority rankings

Evaluation items	Evaluation index		Entire weighted values	Entire rankings
	Indices	Weighted value		
Psychological factors 0.1849	Interests	0.0897	0.0166	12
	Psychological confidence	0.6070	0.1122	3
	Emotional stability	0.3033	0.0561	7
Physical factors 0.5600	Tests on physical capability	0.0591	0.0331	9
	Solve stresses	0.1540	0.0862	4
	Improvement of physical strength	0.4397	0.2462	1
	Restore physical vitality	0.3472	0.1944	2
Environmental factors 0.0335	Cleanness of facilities and places	0.6227	0.0209	11
	Modernization of facilities and equipments	0.3113	0.0104	13
	Interior of facilities and places	0.0660	0.0022	16
Social factors 0.0987	Relationship with therapists	0.6651	0.0656	6
	Relationship with peers	0.2311	0.0228	10
	Consideration for other people	0.1038	0.0102	15
Mental health factors 0.1230	Symptoms of physical constitution	0.5455	0.0671	5
	Symptoms of melancholia	0.3700	0.0455	8
	Symptoms of anxiety	0.0845	0.0104	14

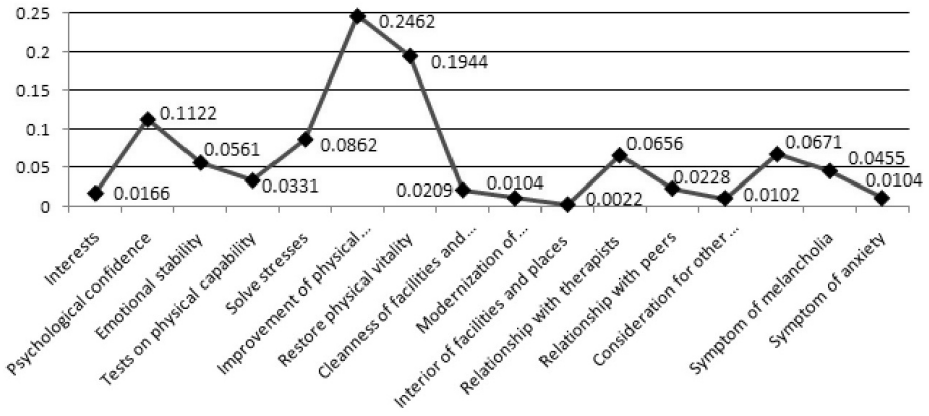

Fig. 3. Analyses of weighted values with regard to indices.

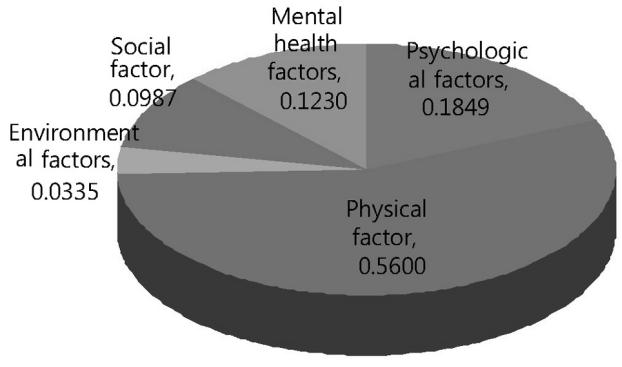

Fig. 2. Status of weighted values with regard to evaluation items.

rankings were analyzed based on data of 59 people by excluding 14 people with CR >0.2 among the 73 participants who answered the questionnaires (Table 4).

Weighted values are the priorities between the indexes included in evaluation index, entire weighted values are the multiplication of evaluation items and weighted value, mean priorities for 16 index.

Analyses of weighted values with regard to evaluation items

As the result of analyses of weighted values regarding evaluation items, physical factors ranked highest at 0.5600, followed by psychological factors and mental health factors.

Considering that answerers of the questionnaires were having or had experiences of muscular system or cardiovascular system diseases, the results shown in Fig. 2 were analyzed further. In addition, it was shown that lots of attentions were given to not only physical treatment through swimming but also to 'psychological factors' such as psychological confidence or emotional stability. However, it was found out that lots of attentions were not given to environmental factors such as facilities or equipments of exercise treatment. Like this, it was analyzed that most of answerers of questionnaires had relatively high interests in physical restoration through treatment processes through

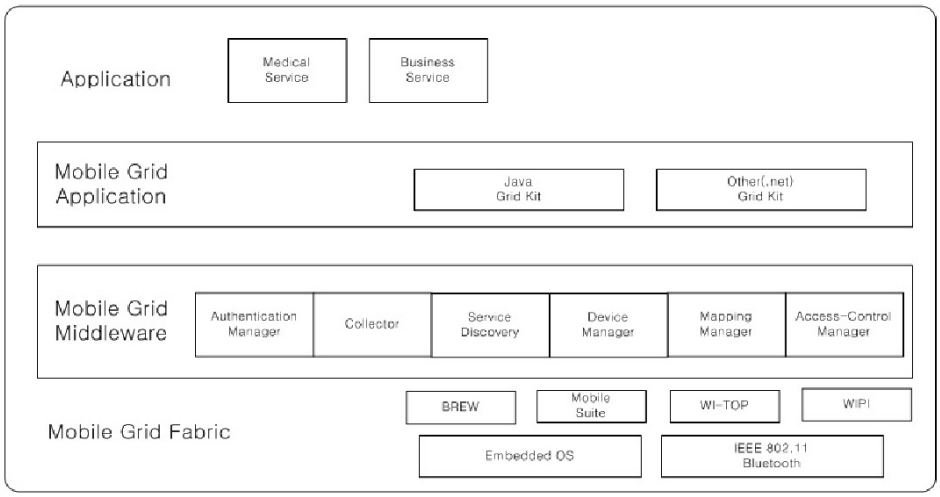

Fig. 4. Depiction of grid structure.

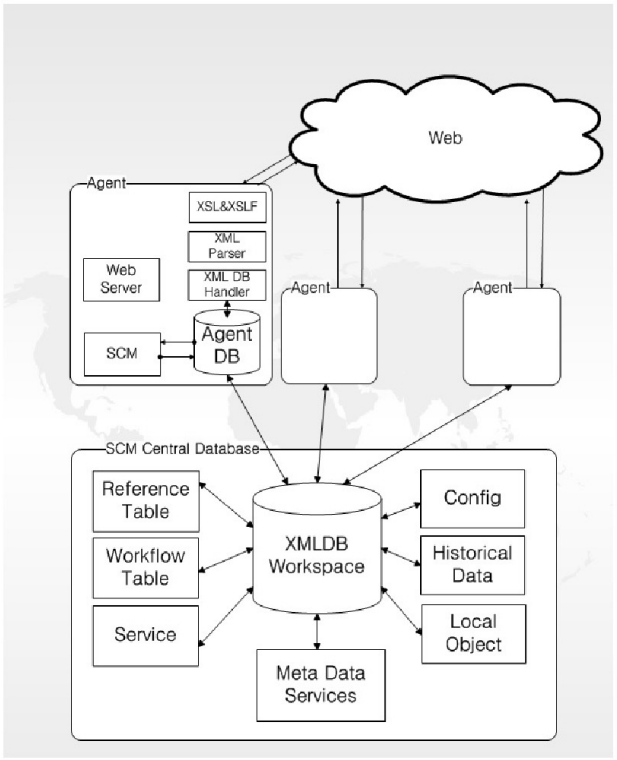

Fig. 5. Structure of SCM.

swimming exercises and psychological confidence according to physical restoration.

Fig. 3. depicts the result of analyses of the entire priority rankings for the 16 indices. An index, which acquired the highest weighted value, was 'improvement of physical strength' with the value of 0.2462. The second was an index of 'restoration of physical vitality' with acquisition of value of 0.1944. Two indices were all indices included in "physical factor" items. An index acquired the third highest weighted value was 'psychological confidence' and acquired value of 0.1122. Indices with the highest weighted values among the entire 16 indices were shown as indices belonged to "physical factor" and "psychological factors" items. And indices acquired low weighted values were 'consideration for other people (0.0102)' and 'interior of facilities and places (0.0022)' and were indices each belonged to social factors and environmental factors items respectively.

Analyses of weighted values with regard to indices

When analyzed these results, it was shown that indices with higher connection with physical treatments acquired relatively high weighted values. This was the same analyses showing the consistency with priority rankings of five evaluation items. One thing to consider was the point that even indices with lower weighted values shall not be ignored in the processes of exercises treatments through swimming. It means that all indices play an important role in the processes of treatments while there are only differences in relative level of importance between each index. Therefore, 16 indexes drown out this study in different degree have a positive impact on the patient attending swimming exercise treatment.

DISCUSSION

The present study has documented a system capable of real-time handle on real-time having agents in all environment such as mobile environment for processing on real-time, computer communication environment, and radio communication was suggested. Grid structure was used as seen in (Fig. 4) for processing questionnaires and diagnoses and treatments. It was designed so that data processing is smooth between different devices by using grid structure.

Agents based supply chain management (SCM) structure was expressed in Fig. 5. It was designed to realize in net environment by expressing relation information model in XML through SCM structure. Agents collect information respectively and store in DB for processing at work space together.

In summary the factors providing impacts on exercise treatments were collected for management system design

of efficient swimming exercise treatments for patients' management were established and through Fuzzy AHP technique, weighted values and priority rankings between each index were drawn out.

It is judged that this research can find meanings in the following aspects; First, level of importance of exercise treatment was drawn out in a position of patients. For establishing exercise treatment system, exercises were applied for the purpose of treatments with objects of patients having or had experiences of muscular system diseases and cardiovascular system diseases and in particular, factors people feel physically and mentally through swimming were re-arranged.

Second, level of importance (relative importance) for each factor was converted into quantity. Exercise treatments until now were conducted from viewpoints of therapists. However, in this research, main interest indices from viewpoints of patients were classified and level of importance of each index was converted into quantity and its feasibility was verified.

Third, absurdity of questionnaires was minimized using fuzzy theory. In this research, before calculating weighted values and priority rankings of the questionnaires data, it was converted into numbers by using triangular fuzzy number which is one of fuzzy theories. Judgment of people can be inaccurate or absurd. Therefore, it is believed to be meaningful attempt that qualitative judgments was expressed in quantity by using fuzzy theory for acquiring more accurate data.

Fourth, patient management system was modeled by using IT technology.

In this research, agents based system possible for real-time processing was designed. Patient management system possible to process on real-time data generating during treatment processes of patients using agents was designed. Like this, this research has converted factors providing impacts on swimming exercise treatment into numbers considering positions of patients and its priority rankings were drawn out. In addition, it is judged to be very meaningful research that effects of treatment were attempted to be increased by processing these data on real-time using IT technology.

If the above limits are supplemented in the future, it is expected that more systematic exercise treatment system can be designed as the follows; First, the parts considering mutual connectivity between factors providing impacts on swimming exercise treatments will be added in the future theses by classifying more in detail. Researches on drawing out more accurate weighted values are now undergoing by adding parts regarding to mutual connectivity between evaluation items in addition to grouping of indices which have commonness based on prior research data.

Second, it is lacking of convenience of use of data transmission device. Since lots of activities take place in water due to characteristics of swimming exercise treatments, there are difficulties in using electronics devices. Therefore, it is expected that uses of devices between therapists and patients will become easier if application of terminals possible to use easily in water and ubiquitous sensor network (USN) technology are added.

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