Prognosis and Diagnosis of Osteoporosis with Fuzzy Inference System

Sandeep Singh, Gagandeep Singh, Sandeep Bassi
Assistant Professor
Lyallpur Khalsa CollegeJalandhar , Punjab ,India

***Abstract*-**Whenever a diagnosis is given, different factors have to be deeply understood and be compared depending on different situations and factor combinations to place the final verdict. Due to the different levels of concentrations or strengths of the various factors, there is a probability of getting best as well as worst combinations. The factors need to be analyzed with their concentration values according to different case and is one of the most tedious tasks. In this paper, the fuzzy set theory is combined to handle uncertainties (arising from deficiencies of information available from situation like missing factor values). Fuzzy Inference System is the method of mapping from one input to other using fuzzy logics. The process includes steps: Membership Function, Logical Operation, and If-Then Rules. This algorithm converts various factors to fuzzy data and fuzzy data into de-fuzzification.

***Keywords*-** Fuzzy Inference System, Diagnosis, Osteoporosis, If-Then Rules, Membership Functions

I. INTRODUCTION

Whenever some diagnosis is made, the variation in the strengths of various factors lead to changes in the identification of the disease. Fuzzy logic processing is the niche of all approaches that comprehend, represent and develop the input factors, their segments and structures as fuzzy sets. The depiction and processing rest on the selected fuzzy method and on the problem to be cracked. The logic of fuzzy sets is easy, simple and realistic. For example, we want to define a set of gray levels that share the property dark. In original set theory, one has to find a threshold limit, example level 100. All levels between 0 and 100 are parts of this set. But the higher level or more intensity is a matter of degree. So, a fuzzy set can model this property much better. Fuzzy logic thinks like and works like human as fuzzy logic is built on the assemblies of qualitative explanation used in daily talks. Fuzzy logic is required where clarifying system is capable of reasoning with vague and inexact information [1].

Fig.1: Enhancement model using Fuzzy Inference System

II. FUZZY RULE BASED APPROACH

If we infer the disease signs of osteoporosis, as verbal variables, then we can use fuzzy if-then rules to section the factors into dif-ferent areas. A fuzzy segmentation rule can be created as follows [3]:

IF the aspect is intense yes AND next aspect is also intense AND difference is no THEN it is 100% intense for joint aspect strength.

A. Fuzzy logic is theoretically easy to comprehend

The mathematical ideas behind fuzzy intellect are very modest. Fuzzy logic is a more instinctive method without the big difficulty.

B. Fuzzy logic is stretchy.

With any given system, it is easy to coat on more function-ality without doing it from basic.

C. Fuzzy logic is lenient of vague data

Everything is inexact if you understand closely enough; also, most things are inexact even with precise checking. Fuzzy reasoning builds this thoughtful decision-making system.

D. Fuzzy logic can handle nonlinear functions of ran-dom complexity

Fuzzy logic can entertain nonlinear functions of random complexity. Fuzzy system can work with any set of input-output data. This process is made mainly relaxed by Fuzzy Logic Toolbox techniques like adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS).

E. Fuzzy logic can be built on top of the experience of experts

In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already understand your system.

F. Fuzzy logic can be mixed with predictable control techniques

Fuzzy systems are not a new method for predictable control methods. It just makes the implementation easy.

G. Fuzzy logic is built on natural linguistic.

The basis for fuzzy logic is the basis for human communi-cation. This remark supports many of the other declarations about fuzzy logic that it is built on the structures of qualitative explanation used in normal language and thus, fuzzy logic is easy to comprehend.

III. FUZZY INFERENCE SYSTEM

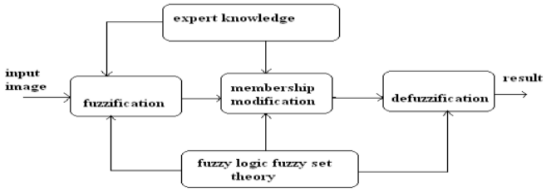

Fig.2: Fuzzy Inference System

Fuzzy inference is the process of expressing the drawing from one input to another output using fuzzy logics. This helps in deci-sion making, or patterns differentiating. The scheme of fuzzy in-ference system is made up of three steps:

a) Membership Functions
b) Logical Operations
c) If-Then Rules.

There are two forms of FIS - fuzzy inference systems that can be executed in Fuzzy Logic Toolbox: Mamdani FIS and Sugeno FIS. These two forms of inference systems diverge somewhat in the way outputs are created.

Fuzzy inference systems have proved to be good decision-making tool in fields such as automatic controls, data organization, decision study, expert systems, and computer vision. And because of its flexible approach, fuzzy inference systems are related with a number of methods, such as fuzzy-rule-based systems, fuzzy modelling, fuzzy expert systems, fuzzy associative memory, and fuzzy logic controllers, and also fuzzy systems.

Mamdani's fuzzy inference system is the common used type. Mamdani's method was developed first in 1975 by EbrahimMamdani [7] as a trial to control a steam engine and boiler combination by creating a set of linguistic control rules got from skilled human operators. His effort was based on Lotfi Sade's 1973 research paper on fuzzy algorithms or complex systems and decision processes [8]. Mamdani-type inference says that output membership functions should be like fuzzy sets. After the aggregation step, there should be fuzzy set for each output variable that is to be defuzzied. It is effective, to use a single spike as the output membership functions rather than a distributed fuzzy set. Such an output is sometimes described as a singleton output membership function, and it can be considered of as a pre-defuzzied fuzzy set. It improves the efficiency of the defuzzification method as it reduces the computation required by Mamdani type, where centroid of a two- dimensional function is calculated. Rather than participating across the two-dimensional function to find the centroid, we can use the weighted average of a few data points. Sugeno-type systems support this type of model and can be used to model any inference systems in which the output membership functions are either linear or constant.

A. Basic Conceptions of Fuzzy Logic

The main approach of fuzzy inference is taking input variables used to diagnosis of severity of the osteoporosis through a mechanism which is comprised by parallel If-Then rules and fuzzy logical operations, and then reach the output space. The If-Then rules are expressed directly as human conditional language, where each of the word is considered as a fuzzy set. All of these fuzzy sets are necessary for creation of membership functions before they are used as If-Then rules of FIS.

B. Fuzzy Set

Fuzzy set is an improved version of the set theory. In set theory, the membership of elements conforms with a binary logic either the unit belongs to the crisp set or the unit does not. While in fuzzy set theory, it can contain elements with degree of membership between completely belonging to the set or vice versa. This is because a fuzzy set lacks a clear boundary and its fuzzy boundary is defined by membership functions thereby stsating degree of membership of elements to range from 0 to 1.

C. Membership Functions

A membership function (MF) is a curve that describes the aspect of fuzzy logic by assigning to each factor of the corresponding membership cost, or degree of membership. It plots each input to a membership value in a closed unit interval [0, 1].

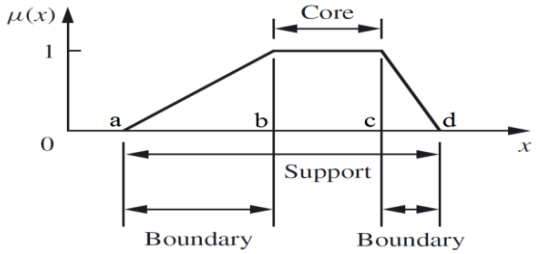

Fig.3: Description of Fuzzy Member Function

There are five types of membership function: Triangle MF, Generalized Bell MF, Trapezoidal MF, Gaussian MF, and Sigmoidal MF. Irrespective of the size, shape, a single membership function may only state one fuzzy set. More than one membership function (MF) are used to describe a single input variable. For example speeds of a fan, a three-level fuzzy system with fuzzy sets 'Low', 'Medium' and 'High' is created.

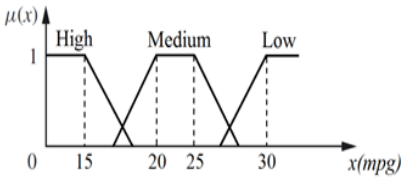

Fig.4: Range division of Fuzzy Member Function

D. Logical Operations

As we know, the standard binary logic is a special case of fuzzy logic where the membership values are always 1 (completely true) or 0 (completely false), fuzzy logic must embrace the consistent logical operations as the typical logical operations. The prime logical operations are NOT, OR and AND. Unlike standard logical operation, the operands A and B are mem-bership values within the interval [0, 1]. In fuzzy logical operations, logical AND is expressed by function min,

so the statement A AND B is equal to min (A, B). Logical OR is defined by function max, thus A OR B becomes equivalent to max (A, B). And logical NOT makes operation NOT A become the operation 1 – A.

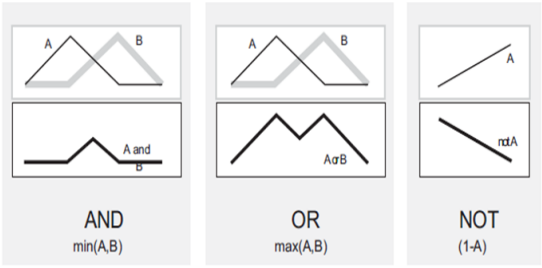

Fig.5: Logical Expression of If-Then Rules

IV. LITERATURE REVIEW

The past work on this topic has been contributed by well named Reshmalakshmi, C., and M. Sasikumar et al. [1] The goal of this paper is to propose a FIS framework for diagnosis of osteoporosis disease. The idea behind such a framework is to assist the doctor to detect, control and give treatment to various forms of osteoporosis. The intensity of the ailment is calculated by fuzzy expert system and conservative X-ray image processing method. Main benefit of projected algorithm is that to performs as an expert diagnosis and in second part X-ray imaging system computes bone density. The contribution of membership functions and If-then rules along fuzzy edge directed image interpolation (FEDI) system helps design an effectual osteoporosis detection system. The wide experimentations conducted on multiple patients have demonstrated that the projected algorithm can change the existing, expensive and not readily available bone density calculation procedures in this field.

Chen, Po-Chen, and MladenKezunovic.et al [2] Cold and hot climate are primary causes of distribution of power cuts. To develop methods to ease weather influences, a fuzzy logic system for decision making is proposed in this paper. It allows workers to achieve more accurate power cut predictions and optimize real time operation and maintenance scheduling. A fresh approach for weather-driven risk assessment method is applied to process the data and generate risk charts for better decision making for outage control. The use of weather information in reducing FL time, an important performance improvement in power management.

Chaudhari, Swati, ManojPatil, et al. [3] The fuzzy inference system with weighted average good for changing nonlinear system control. The system finds best decision-making results. In these systems difficulties with high order polynomials and a substantial computational load rises when used separately. Multiple processing approach with weighted average and de-fuzzification set in layers can decrease the cost of de-fuzzification and absence of output lucidity that causes risk when used as a controller. The adaptive fuzzy system with this tactic makes the system useable for areas needing easy clarification and human intellect. In this paper, analysis of fuzzy inference systems is done and a new multilayer system with de-fuzzification and weighted average is enlightened.

Barrett-Connor, Elizabeth, et al. [4] Osteoporosis and 1-year fracture risks were studied in 197,848 postmenopausal American women from five race groups. Weight elucidated alterations in BMD, except among blacks, who had the highest BMD. One SD decrease in BMD predicted a 50% amplified fracture risk in each group. Absolute fracture rates differed despite of other factors. Most material about osteoporosis generates from revisions on white women. This study describes the occurrence of osteoporosis and the association between BMD and fracture in women from five race groups.

Hashemi, Atiyeh, Abdol Hamid Pilevar, et al. [5] Lung cancer is identified by presenting one of the highest occurrences and one of the highest rates of death among all other sorts of cancers. Detection of this disease in the initial stages helps the patients with a high chance of survival. In this paper, work targets at detecting lung nodules by detection from computerized tomography (CT) scan. And this paper concentrates on describing a method to improve the efficiency of the lung cancer diagnosis by a region growing segmentation method of lung images. Later, cancer recognition is done by Fuzzy Inference System (FIS) for differentiating between malignant, benign and advanced lung nodules. In the future scope of this paper testing helps in diagnosing performances of FIS system by using artificial neural networks (ANNs).

Chaudhari, Swati, ManojPatil, et al. [6] The FIS system with weighted average is efficient and useful for dynamic nonlinear system control while the system that de-fuzzifies the fuzzy output into crisp is best suited for decision making and control. However, in these systems complexities with high order polynomials and a substantial computational burden rises when used separately. Multilayer approach with weighted average and de-fuzzification set in layers can reduce the cost of de-fuzzification and lack of output expressivity that causes risk when used as a controller. The adaptive fuzzy system with this approach makes the system exploitable for areas requiring easy interpretation and human reasoning. In this review paper, there is the study of fuzzy inference systems and the proposed multilayer system with de-fuzzification and weighted average is explained.

Qu, C., &Buyya, R. et al. [7] Cloud computing helps to use resources which are not physically present in a system. This provides an imaginary computing resources. A cloud benefits can extend from user selecting the appropriate cloud services that can be used to fulfil functional to non-functional requirements. This is a cumbersome work due to large number of available services, users' undistinguishable requirements, and performance distinctions in cloud. In this paper, a method is developed that calculates high confidence of clouds with respect to fuzzy Quality of Service (QoS) and services' dynamic performances to facilitate service selection.

Cakit, E., &Karwowski, W. et al. [8] Fuzzy inference system analyses relation between adverse events and infrastructure development investments. This can be realized by the number of adverse events in an active war theater. The measured model input variables included the total number of economic improvement projects and their related budgets at different time periods in Afghanistan between 2002 and 2009. Six

different forecast models were developed and tested. The forecast accuracy of each FIS model was assessed and associated based on the mean absolute errors (MAE). At the end, we found that the FIS is a useful modeling approach that can be applied under scenario-based conditions to support decision makers in analyzing ancient economic data on how allocation of provincial infrastructure development funds can best help reducing the onset of adverse events in an active war theater.

Liang, Sheng-Fu, Chih-En Kuo, et al. [9] A genetic fuzzy inference system based on expert knowledge for automatic sleep stage detection was developed. Few methods used were Eight features, including temporal and spectrum analyses of the EEG and EMG signals, were utilized as the input variables. The fuzzy rules and the fuzzy sets were built based on expert knowledge and the circulations of feature values at different sleep stages. In this paper, three was were designed to develop and evaluate the proposed system. PSGs of 32 human and 16 human with insomnia were included in the experiment to develop and evaluate the proposed method.

Gupta, Gunjan, Manish K. Srivastava [10] Location of a tourist hotel is always a super criterion for the tourist, and this is a typical task for the hotelier to take a decision on it. Therefore, the main aim of this work is to design a fuzzy inference system to take a decision for the section of tourist hotel. Here the method of fuzzy set theory and fuzzy logic process are used to consolidate decision-makers assessments about criteria weighting. An empirical study is made for indentifying the international tourist hotel location in India and also to highlight the effectiveness of fuzzy model proposed. Thus, this work proposes a simple and practical decision model that will provide significant managerial insights to evaluation committees when making location selection. It will also help committee members to understand the organizational goal and decision process.

V. METHODOLOGY

This chapter explains the in methodology adopted for the implementation of the Mamdani Fuzzy Inference System (FIS) for the prognosis of the osteopenia and osteoporosis disease [18,19].

The First step is to design Fuzzy Input variables for the fuzzification to take place:

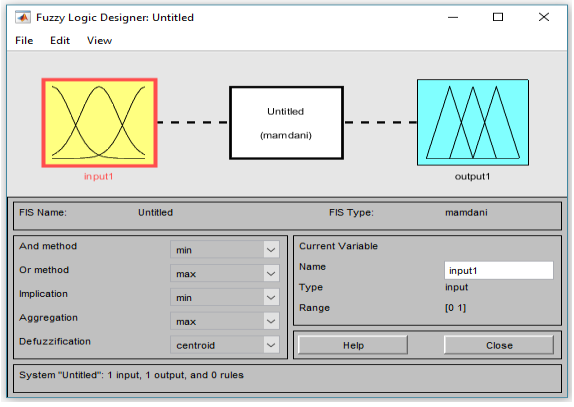

Fig.6: Displays the console of Fuzzy Inference System

In this work, we have defined all together 11 Member Functions which act as Input Variables and 01 Output Function which provides the final output based on the variations on the intensities of the factors affecting condition of the human being.

This is the new Proposed factor in my work, Nationality is important factor to study the effect of bone density on the osteoporosis. The nationality varies the amount of Vitamin D absorbed by the human skin [21]. African are less prone to bone damages, where are Americans are more susceptible. The middle range is occupied by the Indian Nationality. This factor is applicable for both men and women [22]. In my work, this is a new factor which over comes the limitation of the previous work done.

The Bone Structure is categorized into 3 slabs, No Fracture, Hairline Fracture, Severe Fracture. This factor eliminates the use of expert opinion. The basic fracture condition can be observed by any human bye naked eyes. The fracture severity can be observed from the radiography report or the X-Ray of the affected joint. The first range defines no fracture or minor bruises which are considered as normal [19]. Second range defines the case with higher porosity and is named as hairline fracture. The last range is the severe most. It makes evident the person is at higher risk due to the intensity value in this range.

VI. OUTPUT VARIABLE

The Output variable gives the intensity or severity of the Osteopenia/Osteoporosis. The output is divide into 3 main ranges. The range differs with respect to T-Score available as the result of Fuzzy Inference System Evaluation. The first range is from -5 to -2.5 this range defines that patient is suffering from Osteoporosis and is on higher risk of bone damage.

The T-Score Range of -3.5 to -0.5 is the middle range which defines the case of osteopenia [18]. This range marks mild osteopenia or the beginning. General this range is covered by majority of the cases. The last and the highest T-Score range marks Normal condition as the output. Here the chances of bone injury is least.

The 11-member function are defined which provide the input variable with variable factor strengths having 2 to 4 ranges of each factor. Some of the factors are from previous researches and 02 are from new survey [21]. The two new factors “Nationality” and “Bone Structure” has been implemented to get more precise result.

The survey defines that the out of American, Indian and African race, Americans are at higher risk of bone weaknesses due to poor diet habits [22] and Africans are less susceptible as melanin content in the skin absorbs more vitamin D [16].

VII. RESULTS

TABLE I. RESULTS TABLE 1

S. No.	*Age*	*Gender*	*Heredity*	*BMI*
1	Young	Male	No	Underweight
2	Young	Female	No	Underweight
3	Young	Female	No	Obese
4	Old	Male	No	Obese
5	Old	Male	No	Underweight
6	Middle	Male	No	OverWeight
7	Old	Male	Yes	OverWeight
8	Old	Male	Yes	OverWeight
9	Middle	Male	Yes	OverWeight
10	Middle	Female	Yes	OverWeight

TABLE II. RESULTS TABLE 2

S. No.	Painful	Calcium Deficiency	Years Since Menopause	Alcohol/Cigarette	Physical Stress
1	Mild	Low	Not Applicable	Low Consumption	Medium
2	Mild	Low	1-5- Years	Low Consumption	Medium
3	Mild	Low	1-5- Years	Low Consumption	Medium
4	Severe	Low	Not Applicable	Low Consumption	Medium
5	Severe	Medium	Not Applicable	Moderate Consumption	High
6	Severe	Medium	Not Applicable	Moderate Consumption	High
7	Severe	Medium	Not Applicable	High Consumption	High
8	Severe	High	Not Applicable	High Consumption	High
9	Severe	High	Not Applicable	Low Consumption	High
10	Severe	High	More than 5 Years	Low Consumption	High

TABLE III. RESULTS TABLE 3

S. No.	*Nationality*	*Bone Structure*	*Condition*	*Percentage*
1	African	Low Porosity	Normal	22%
2	African	Low Porosity	Normal	37%
3	African	Highly porous	Osteopenia	47%
4	Indian	Highly porous	Osteopenia	49%
5	Indian	Moderate Porosity	Osteopenia	48%
6	American	Moderate Porosity	Normal	37%
7	American	Highly porous	Osteopenia	63%
8	Indian	Highly porous	Osteoporosis	69%
9	Indian	Highly porous	Osteopenia	54%
10	Indian	Highly porous	Osteoporosis	74%

VIII. CONCLUSION

This work is an expert system combined with X-Ray reading and has been successfully applied in fuzzy domain to diagnose Osteopenia and Osteoporosis. The diagnosis is a two-step way where first part deals with selecting input variables and their intensity as per the case and in second part X-ray based factor in input for the prognosis of bone structure. The expert system identifies the degree of disease with the help of carefully designed membership function and rules. The proposed diagnosis system contributes to the field of medical sciences for the diagnosis purpose. Fuzzy evaluation presents with aggregated results based on the input variable strength concentrations used for the Mamdani FIS evaluator. This efficient algorithm helps in precise and early detection of the Osteopenia and Osteoporosis.

IX. REFERENCES

[1]. Reshmalakshmi, C., and M. Sasikumar. "Fuzzy inference system for osteoporosis detection." Global Humanitarian Technology Conference (GHTC), 2016. IEEE, 2016.

[2]. Chen, Po-Chen, and MladenKezunovic. "Fuzzy Logic Approach to Predictive Risk Analysis in Distribution Outage Management." IEEE Transactions on Smart Grid 7.6 (2016): 2827-2836.

[3]. Chaudhari, Swati, ManojPatil, and JalgaonBambhori. "Study and review of fuzzy inference systems for decision making and control." American International Journal of Research in Science, Technology, Engineering &, Mathematics 5.1 (2014): 88-92.

[4]. Barrett-Connor, Elizabeth, et al. "Osteoporosis and fracture risk in women of different ethnic groups." Journal of bone and mineral research 20.2 (2005): 185-194.

[5]. Das, A. K., Anh, N., Suresh, S., &Srikanth, N. (2016). An interval type-2 fuzzy inference system and its meta-cognitive learning algorithm. Evolving Systems, 7(2), 95-105.

[6]. Siahbazi, Alireza, Ali Barzegar, MahmoodVosoogh, AbdolMajidMirshekaran, and Samira Soltani. "Design Modified Sliding Mode Controller with Parallel Fuzzy Inference System Compensator to Control of Spherical Motor." International Journal of Intelligent Systems and Applications 6, no. 3 (2014): 12.

[7]. Hashemi, Atiyeh, Abdol Hamid Pilevar, and Reza Rafeh. "Mass detection in lung CT images using region growing segmentation and decision making based on fuzzy inference system and artificial neural network." International Journal of Image, Graphics and Signal Processing 5.6 (2013): 16.

[8]. Andonovski, Goran, et al. "Evolving fuzzy model based performance identification for production control." Evolving and Adaptive Intelligent Systems (EAIS), 2016 IEEE Conference on. IEEE, 2016.

[9]. Elmazi, Donald, et al. "F3N: An Intelligent Fuzzy-Based Cluster Head Selection System for WSNs and Its Performance Evaluation." Mobile Computing and Wireless Networks: Concepts, Methodologies, Tools, and Applications. IGI Global, 2016. 1033-1048.

[10]. Menghal, P. M., and A. Jaya Laxmi. "Fuzzy Based Real Time Control of Induction Motor Drive." Procedia Computer Science 85 (2016): 228-235.

[11]. Weaver, C. M., et al. "Erratum and additional analyses re: Calcium plus vitamin D supplementation and the risk of fractures: an updated meta-analysis from the National Osteoporosis Foundation." Osteoporosis International 27.8 (2016): 2643-2646.

[12]. Naylor, K. E., et al. "Response of bone turnover markers to three oral bisphosphonate therapies in postmenopausal osteoporosis: the TRIO study." Osteoporosis International 27.1 (2016): 21-31.

[13]. Bayani, Mohammad Ali, et al. "The Relationship Between Type 2 Diabetes Mellitus and Osteoporosis in Elderly People: a Cross-sectional Study." International Biological and Biomedical Journal 2.1 (2016): 39-46.

[14]. Jiang, Xuezhi, et al. "Osteoporosis screening in postmenopausal women aged 50–64 years: BMI alone compared with current screening tools." maturitas 83 (2016): 59-64.

[15]. Wu, Chieh-Hsin, et al. "Increased risk of osteoporosis in patients with peptic ulcer disease: a nationwide population-based study." Medicine 95.16 (2016).

[16]. Liu, Yao, et al. "Chronic high dose alcohol induces osteopenia via activation of mTOR signaling in bone marrow mesenchymal stem cells." Stem Cells 34.8 (2016): 2157-2168.

[17]. Salehi-Abari, Iraj. "Early diagnosis of osteopenia/osteoporosis by bone mineral density test using DXA method in early adulthood—a pre-emptive step towards future bone health." International journal of rheumatic diseases 20.1 (2017): 122-125.

[18]. Black, Dennis M., et al. "Fracture risk reduction with alendronate in women with osteoporosis: the Fracture Intervention Trial." The Journal of Clinical Endocrinology & Metabolism 85.11 (2000): 4118-4124. 1082–1087.

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