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Contributing factors and consequences of childhood obesity – An analysis using Induced Fuzzy Cognitive Maps (IFCMs)

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ABSTRACT

Obesity is now a common childhood disease and is widely acknowledged as having become a global epidemic. There are well-recognized health consequences of childhood obesity, both during childhood and adulthood, affecting health and psychological welfare. Childhood obesity is a risk factor for adult morbidity and mortality, independent of body mass index (BMI) in adulthood, family history of cardiovascular disease or cancer, and smoking. The present study was designed with the objectives to study contributing factors of childhood obesity like genetic, environmental, behavioral, metabolic, biochemical and social factors and its relationship. Hence, this research investigates the most contributing / impactful factor of childhood obesity using Induced Fuzzy Cognitive Maps (IFCMs). IFCMs are a fuzzy-graph modeling approach based on expert's opinion. This is the non-statistical approach to study the problems with imprecise information.

Introduction

Obesity is the most important nutritional disorder of the industrialized world and is also creeping slowly but steadily into the developing countries. Childhood obesity is a complex disease with different genetic, metabolic, environmental and behavioral components that are interrelated and potentially confounding, thus making casual pathways difficult to define[1].

Genetic factors may impart susceptibility to obesity but cannot alone be responsible for epidemic of obesity in such a short span[14]. Environment factors like increase in the availability and marketing of foods, increase in the use of computers and television viewing , greater reliance on motor vehicles for transport, reduction in physical education in schools and physical activity at work are all major determinants of obesity [1,2].

Behavioral factors like high intake of food, low physical activity, excessive sugar intake by soft drink [1,2] have been playing major roles in the rising rate of obesity.

Although genetics are undeniably important in obesity genesis, they form part of a complex interaction with many other environmental, behavioral and metabolic factors. Birth weight, timing or rate of maturation and gestational diabetes are all contributed to the onset of obesity. It has also been established that social factors like ethnicity and social and economic deprivation[2,3] are important determinants of obesity.

The current study examines the contributing factors of childhood obesity and analyses the most impactful factor of childhood obesity using Induced Fuzzy Cognitive Maps(IFCMs). An efficient knowledge-based approach utilizing the method of Fuzzy Cognitive Maps(FCMs) is presented in this research work.

Fuzzy Cognitive Maps (FCMs) is a well established technique for prediction and decision making especially for situations where fuzziness and uncertainty exists. To deal imprecise information, Lofti A.Zadeh,1965, introduced the notion of fuzziness. In 1986, Kosko [8], the guru of fuzzy logic introduced the Fuzzy Cognitive Maps. It was a fuzzy extension of the Cognitive Map pioneered in 1976 by Political Scientist Robert Axelrod, who used it to represent knowledge as an interconnected, directed, bilevel-logic graph[4]. Thus the FCM plays a vital role in modeling system.

This paper describes the method of analyzing the most contributing factor in childhood obesity using Induced Fuzzy Cognitive Maps(IFCMs) which is the advanced study of FCM[15].

It is worth mentioning here, the book entitled 'FCMs and Neutrosophic Cognitive Maps' by Vasantha and Smarandache, 2003[16]. This book infers that FCMs strongly resemble neural networks and powerful for reaching consequences as a mathematical tool for modeling complex systems.

Implications for interdisciplinary reading: National Implication by Calais[7], FCM based tool for prediction of infectious diseases by Elpiniki et al.,[7], Benefits of literacy in Bhutan by Devadoss et al. [18], Problem faced by bonded labourers near Kodaikanal forests discussed and solution given by Vasantha [17] are notable studies in this area of research. In all the above studies, the various real life with imprecise information taken and the precise solutions given by FCM and its advanced studies.

In the current study, Section1 overviews the Fuzzy Cognitive Maps theory, and its influence. Section2 explains the Algorithmic approach of IFCM models. Section3 discusses the possible components(attributes) contributes the Childhood Obesity. Section4 gives implementation of IFCM model and Section5 reveals the discussion of the proposed work.

Fuzzy Cognitive Maps

Fuzzy Cognitive Maps(FCMs) are digraphs that capture the cause/effect relationship in a system. Nodes of the graph stand for the concepts representing the key factors and attributes of the modeling system, such as inputs, variable states, components,

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factors, events, actions of any system. Signed weighted arcs describe the casual relationships, which exists among concepts and interconnect them, with a degree of casuality. The constructed graph clearly shows how concepts influence each other and how much the degree of influence is.

Cognitive Maps(CMs) were proposed for decision making by Axelrod [5] for the first time. Using two basic types of elements; concepts and casual relationship, the cognitive map can be viewed as a simplified mathematical model of a belief system. FCMs were proposed with the extension of the fuzzified casual relationships. Kosko[8], introduced FCMs as fuzzy graph structures for representing casual reasoning. When the nodes of the FCM are fuzzy sets then they are called fuzzy nodes. FCMs with edge weights or casualities from the set {-1, 0, 1} are called simple FCMs.

Consider the nodes/concepts $P_1, P_2, P_3, \ldots P_n$ of the FCM. Suppose the directed graph is drawn using edge weight e_{ij} from {-1,0,1}. The matrix M be defined by $M=(e_{ij})$ where e_{ij} is the weight of the directed edge P_iP_j . M is called the adjacency matrix of the FCM, also known as connection matrix.

The directed edge e_{ij} from the casual concept P_i to concept P_j measures how much P_i causes P_j . The edge e_{ij} takes values in the real interval [−1, 1].

$e_{ij} = 0$ indicates no casuality.

$e_{ij} > 0$ indicates casual increase / positive casuality.

$e_{ij} < 0$ indicates casual decrease / negative casuality.

Simple FCMs provide quick first-hand information to an expert's stated casual knowledge. Let $P_1, P_2, P_3, \ldots P_n$ be the nodes of FCM. Let $A = (a_1, a_2, \ldots a_n)$ is called a state vector where either $a_i = 0$ or 1. If $a_i = 0$, the concept a_i in the OFF state and if $a_i = 1$, the concept a_i in the ON state, for i = 1, 2, . . . , n. Let $P_1P_2, P_2P_3, \ldots P_iP_j$ be the edges of the FCM ($i \neq j$). Then the edges form a directed cycle.

An FCM is said to be cyclic if it possesses a directed cycle. An FCM with cycles is said to have a feedback, when there is a feedback in an FCM, i.e., when the casual relations flow through a cycle in a revolutionary way, the FCM is called a dynamical system. The equilibrium state for the dynamical system is called the hidden pattern. If the equilibrium state of a dynamical state is a unique state vector, it is called a fixed point or limit cycle. Inference from the hidden pattern summarizes the joint effects of all interacting fuzzy knowledge.

Algorithmic Approach in IFCM

Even though IFCM is an advancement of FCM it follows the foundation of FCM, it has a slight modification only in Algorithmic approaches. To derive an optimistic solution to the problem with an unsupervised data, the following steps to be followed:

Step 1: For the given model (problem), collect the unsupervised data that is in determinant factors called nodes.

Step 2: According to the expert opinion, draw the directed graph.

Step 3: Obtain the connection matrix, M_1, from the directed graph (FCM). Here the number of rows in the given matrix = number of steps to be performed.

Step 4: Consider the state vector C_1 which is in ON position. Find $C_1 \times M_1$. The state vector is updated and threshold at each stage.

Step 5: Threshold value is calculated by assigning 1 for the values > 0 and 0 for the values < 1. The symbol ' →' represents the threshold value for the product of the result.

Step 6: Now each component in the C_1 vector is taken separately and product of the given matrix is calculated. The vector which has maximum number of one's is found. The vector with maximum number of one's which occurs first is considered as C_2.

Step 7: When the same threshold value occurs twice. The value is considered as the fixed point. The iteration gets terminated.

Step 8: Consider the state vector C_1 by setting C_2 in ON state that is assigning the second component of the vector to be 1 and the rest of the components as 0. Proceed the calculations discussed in Steps 4 to 6.

Step 9: Continue Step 9 for all the state vectors and find hidden pattern.

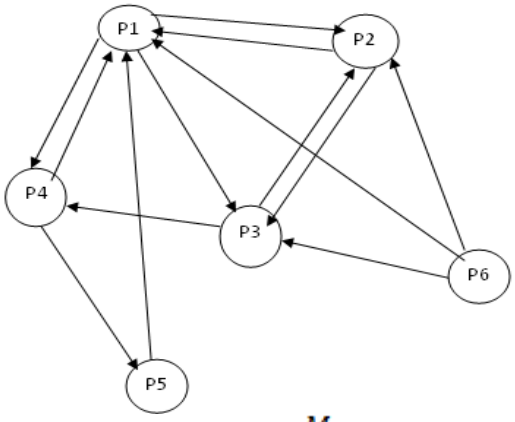
Contributing factors of childhood obesity – strategies

Using the survey and the experts (Doctors) opinion, We have taken the following six concepts(factors) as {P1,P2,P3,P4,P5,P6}. The following factors are taken as the main nodes for our studies:

P1 – genetic factors
P2 – environmental factors
P3 – behavioral factors
P4 – metabolic factors
P5 – biochemical factors
P6 – social factors.

Implementation of IFCM model to the study

Based on the Experts' opinion, the directed diagraph is drawn as follows:



The corresponding connection matrix M_1 is given as

$$M_1 = \begin{pmatrix} 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 \end{pmatrix}$$

Step 1:

Let us consider C_1 in the step1, by setting the concept P1 to ON state i.e., the first component of the vector is set to be 1 and the rest are assigned to 0.

$C_1 = (1\ 0\ 0\ 0\ 0\ 0)$

$C_1 \times M_1 = (0\ 1\ 1\ 1\ 0\ 0) \rightarrow (1\ 1\ 1\ 1\ 0\ 0) = C_1^1$

The symbol '→ ' represents the threshold value for the product of the result.

Now, as per the Induced Fuzzy Cognitive Map methodology, each component in the C_1^1 vector is taken separately and product of the given matrix is calculated. The vector which has the maximum number of one's which occurs first is considered as C_2.

The symbol ' ~ ' denotes the calculation performed with the respective vector, C_1^1 .

$C_1^1 X M_1 \sim (1\ 0\ 0\ 0\ 0\ 0) \times M_1 \rightarrow (0\ 1\ 1\ 1\ 0\ 0)$
$\sim (0\ 1\ 0\ 0\ 0\ 0) \times M_1 \rightarrow (1\ 0\ 1\ 0\ 0\ 0)$
$\sim (0\ 0\ 1\ 0\ 0\ 0) \times M_1 \rightarrow (0\ 1\ 0\ 1\ 0\ 0)$
$\sim (0\ 0\ 0\ 1\ 0\ 0) \times M_1 \rightarrow (1\ 0\ 0\ 0\ 1\ 0)$

Therefore, $C_2 = (0\ 1\ 1\ 1\ 0\ 0)$ (the vector which has the maximum number of 1's)

$C_2 \times M_1 = (2\ 1\ 1\ 1\ 1\ 0) \rightarrow (1\ 1\ 1\ 1\ 1\ 0) = C_2^1$

$C_2^1 X M_1 \sim (1\ 0\ 0\ 0\ 0\ 0) \times M_1 \rightarrow (0\ 1\ 1\ 1\ 0\ 0)$
$\sim (0\ 1\ 0\ 0\ 0\ 0) \times M_1 \rightarrow (1\ 0\ 1\ 0\ 0\ 0)$
$\sim (0\ 0\ 1\ 0\ 0\ 0) \times M_1 \rightarrow (0\ 1\ 0\ 1\ 0\ 0)$
$\sim (0\ 0\ 0\ 1\ 0\ 0) \times M_1 \rightarrow (1\ 0\ 0\ 0\ 1\ 0)$
$\sim (0\ 0\ 0\ 0\ 1\ 0) \times M_1 \rightarrow (1\ 0\ 0\ 0\ 0\ 0)$

Therefore, $C_3 = (0\ 1\ 1\ 1\ 0\ 0) = C_2$.

The fixed point is $C_2 = (0\ 1\ 1\ 1\ 0\ 0)$

When the same threshold value occurs twice, the value is considered as the fixed point. The iteration gets terminated and the calculation gets terminated and the calculation for step 2 is performed. Similar to the step 1, consider C_1 by setting C_2 in ON state, i.e., assigning the second component of the vector to be 1 and the rest of the components as 0.

Step 2:

Let us consider C_1 in the step 2, by setting the concept P2 to ON state i.e., the second component of the vector is set to be 1 and the rest are assigned to 0.

$C_1 = (0\ 1\ 0\ 0\ 0\ 0)$
$C_1 \times M_1 = (1\ 0\ 1\ 0\ 0\ 0) \rightarrow (1\ 1\ 1\ 0\ 0\ 0) = C_1^1$
$C_1^1 X M_1 \sim (1\ 0\ 0\ 0\ 0\ 0) \times M_1 \rightarrow (0\ 1\ 1\ 1\ 0\ 0)$
$\sim (0\ 1\ 0\ 0\ 0\ 0) \times M_1 \rightarrow (1\ 0\ 1\ 0\ 0\ 0)$
$\sim (0\ 0\ 1\ 0\ 0\ 0) \times M_1 \rightarrow (0\ 1\ 0\ 1\ 0\ 0)$

Therefore, $C_2 = (0\ 1\ 1\ 1\ 0\ 0)$
$C_2 \times M_1 = (2\ 1\ 1\ 1\ 1\ 0) \rightarrow (1\ 1\ 1\ 1\ 1\ 0) = C_2^1$
$C_2^1 X M_1 \sim (1\ 0\ 0\ 0\ 0\ 0) \times M_1 \rightarrow (0\ 1\ 1\ 1\ 0\ 0)$
$\sim (0\ 1\ 0\ 0\ 0\ 0) \times M_1 \rightarrow (1\ 0\ 1\ 0\ 0\ 0)$
$\sim (0\ 0\ 1\ 0\ 0\ 0) \times M_1 \rightarrow (0\ 1\ 0\ 1\ 0\ 0)$
$\sim (0\ 0\ 0\ 1\ 0\ 0) \times M_1 \rightarrow (1\ 0\ 0\ 0\ 1\ 0)$
$\sim (0\ 0\ 0\ 0\ 1\ 0) \times M_1 \rightarrow (1\ 0\ 0\ 0\ 0\ 0)$

Therefore, $C_3 = (0\ 1\ 1\ 1\ 0\ 0) = C_2$.

The fixed point is $C_2 = (0\ 1\ 1\ 1\ 0\ 0)$

In the above manner, the other steps to be performed . By keeping each vector in ON position, the various fixed points are found.

Discussion

In this study, we have performed two steps. Result of step1 suggests, by keeping C_1 in ON state, we obtain the hidden pattern $C_2 = (0\ 1\ 1\ 1\ 0\ 0)$. That is, all the 1's in C_2 are the possible factors revealed from the first factor. More precisely, the factors viz., environmental, behavioral and metabolic factors are interrelated and they are in ON state.The biochemical and social factors are in OFF state.

In a similar manner, we can discuss the result of step2. In a step2, we kept C_2 in ON position and we have derived C_2 as the hidden pattern . C_2 contains the factors in ON state are nothing but the factors which are discussed in step1. So by taking environmental factor also, we have obtained the same implications. The factors in ON state are environmental, behavioral and metabolic factors.

First, by observing the above calculation of IFCM done in steps1 and 2, it is explicitly shown that the fixed point vector is taken as the vector which has the maximum number of ones. In both the steps, we have obtained the fixed point vector as $(0\ 1\ 1\ 1\ 0\ 0)$. That is, the factors P1, P2, P3, and P4 are the main implicated factors. Since P5 and P6 are OFF state, the biochemical and social factors do not have more impact on obesity directly.

The second interesting result we can see that the above fixed point vector $(0\ 1\ 1\ 1\ 0\ 0)$ is nothing but the first factor in the casual connection matrix M_1 – genetic factor. So, we can conclude that the genetic factor is the most impactful factor in this study, even though many attributes were present.

Earlier studies in this field, revealed results by concentrating one or two factors alone. But the unique contribution of this study is that various contributing factors that are related have been found and among them the most impactful contributing factor of childhood obesity is also found.

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