Mathematical & Computational Applications, Vol. 3, No. 3, pp. 169-175, 1998

PEDIATRIC NUTRITIONAL REQUIREMENTS: DETERMINATION WITH NEURAL NETWORKS

Bekir Karlık[1] and Aydın Ece[2]

[1] University of Qafqaz , Faculty of Engineering, Department of Computer Engineering, Neriman Nerimanov pr., 103, Baku, Azerbaijan

[2] University of Dicle, Faculty of Medicine, Department of Pediatrics, Diyarbakır, Turkey

Abstract: To calculate daily nutritional requirements of children, a computer program has been developed based upon neural network. Three parameters, daily protein, energy and water requirements, were calculated through trained artificial neural networks using a database of 312 children. The results were compared with those of calculated from dietary requirements tables of World Health Organisation. No significant difference was found between two calculations. In conclusion, a simple neural network may assist physicians in the determination of daily nutritional requirements.

1. INTRODUCTION

Childhood is a dynamic period of life that rapid growth and development take place. Making mistakes in feeding practices of children may lead to undesirable consequences like malnutrition and obesity. The need for reliable and accurate determination of daily dietary requirements of children is widespread. Especially in hasty and crowding circumstances of pediatric clinics and outpatient clinics quick and easy calculation of daily caloric, protein and water requirement is difficult. Use of an automated computer-based technique to assist determination of daily dietary requirements of energy, protein and water has potential for preventing malnutrition and obesity.

2. MATERIALS AND METHODS

A data series of 312 children were obtained from pediatric outpatient clinics. The age, weights and weight percentiles of children were determined and recommended daily dietary requirements for energy, protein and water were calculated on the basis of children's age, sex and weight from tables published by World Health Organisation (WHO) and from other literature (WHO Technical Report Series 1985 and Barness et al. 1986). Then daily values of recommended dietary allowances energy as kcal/d, protein as g/d, water as ml/d have been taught to neural network in a personal computer. After computer training of network, nutritional requirements of same children were computed by artificial neural network, and results derived from both of calculations were compared statistically.

3. ARTIFICIAL NEURAL NETWORK

Artificial neural network (ANN) is a form of artificial computer intelligence. An artificial neural network is a distributed network of computing elements, and may be implemented as a computer software program. It has ability of identifying relations among input data that are not easily apparent with common analytic techniques. Therefore ANN is a good alternative method for solution of difficult problems which are not solved by classical techniques. The functioning of artificial neural network's knowledge is built on learning and experience from previous input data. On the basis of this prior knowledge, the artificial neural networks can predict relations found in newly presented data sets (Pao 1989 and Naylor 1990).

ANN can be separated into subsets. The transfer functions of the elements in these subsets are the same. These little groups are called as layers. Networks is the combination of these layers in a hierarchy. ANN transfer function and local memory element are adjusted according to the relation between input and output signal by a training rule

The multilayered feedforward networks has a better ability to learn the correspondence between input patterns and teaching values from many sample data by the error back-propagation algorithm. Therefore, in this paper we used three-layered feedforward neural network and taught them by error back-propagation (Pao 1989 and Karlik 1994). The neural network's software was written by the investigators and employed back-propagation in a supervised learning paradigm in which the generalised delta rule was used in adjusting the weight values.

The basic structure of ANN used in this study is shown in Figure 1. Here the number of hidden nodes on the hidden layer must be the maximum of the number of input or output nodes. Otherwise training error will be high. As the result of training and tests made, desired output for every input value is introduced to the system by realising the learning rule which changes or adjusts the weights of the network connections depending on the input values or outputs of these inputs. The ANN adjusts itself gradually until realising the input-output relation, which the generalised delta rule was used in adjusting the weight values. The output O_{ij} of each unit ij is defined by,

$$O_{ij} = f(net_{ij}),\ net_{ij} = \sum_i w_{ij} O_i + \theta_j \qquad (1)$$

where O_i is the output of unit i, w_{ij} is the weight of the connection from unit i to unit j, θ_j is the bias of unit j, Σ is a summation of every unit ij whose output flows into unit j, and $f(x)$ is a monotonously increasing function.

When the set of m-dimensional input patterns $\{i_p = (i_{p1}, i_{p2}, \ldots, i_{pm});\ p \in P\}$ where P denotes set of presented patterns, and their corresponding desired n-dimensional output patterns $\{t_p = (t_{p1}, t_{p2}, \ldots, t_{pm});\ p \in P\}$ are provided, the neural network is taught to output ideal patterns as follows. The squared error function E_p for a pattern p is defined by

$$E_p = \frac{1}{2} \sum_{j \in output\ \text{layer}} (t_{pj} - O_{pj})^2 \qquad (2)$$

The purpose is to make $E = \sum_p E_p$ small enough by choosing appropriate w_{ji} and θ_j. To realize this purpose, a pattern $p \in P$ is chosen successively and randomly, and then w_{ji} and θ_j are changed by

$$\Delta_p w_{ji} = -\varepsilon (\partial E_p / \partial w_{ji}) \quad (3)$$
$$\Delta_p \theta_j = -\varepsilon (\partial E_p / \partial \theta_j) \quad (4)$$

where ε is a small positive constant. By calculating the right hand side of (3) and (4), it follows that

$$\Delta_p w_{ji} = \varepsilon \delta_{pj} O_{pi} \quad (5)$$
$$\Delta_p \theta_j = \varepsilon \delta_{pj} \quad (6)$$

where

$$\delta_{pj} = \begin{cases} f'(net_j)(t_{pj} - O_{pj}) & \text{(when j belongs to the output layer.)} \\ f'(net_j)\sum_k w_{kj}\delta_{pk} & \text{(otherwise)} \end{cases} \quad (7)$$

Note that k in the above summation represents every unit k whose output follows into unit j. In order to accelerate the computation, the momentum terms are added on (5), (6),

$$\Delta_p w_{ji}(n+1) = \varepsilon \delta_{pj} O_{pi} + \alpha \Delta_p w_{ji}(n) \quad (8)$$
$$\Delta_p \theta_j(n+1) = \varepsilon \delta_{pj} + \alpha \Delta_p \theta_j(n) \quad (9)$$

where n represents the number of learning cycles, and α is a small positive value (Naylor 1990). In this study, by the iteration the optimum α and ε constant values are as follows: $\alpha = 0.01$, $\varepsilon = 10$.

As the result of training's and tests made, desired output for every input value is introduced to the system by realising the learning rule which changes or adjusts the weights of the network connections depending on the input values or outputs of these inputs. The ANN adjusts itself gradually until realising the input -output relation.

The analysis and neural network training were performed on a Pentium-based personal computer (Pentium 150) and training time took 56 seconds for 2000 iterations. The learning was performed by generalised delta rule. Since dietary requirements of a children are depend on their age, weight and sex, the ANN was configured so data about age, sex, weight and weight percentile of children served as inputs to the networks. Weight percentiles had to be taken as an input data parameter due to great alterations in body weight of children of different percentiles in the same age. These alterations affect network training. To put the results of the neural network analysis into clinical perspectives, data of 312 children aged between 2 months- 15 years were evaluated.

4. STATISTICAL ANALYSIS

The paired samples *t-test* and linear regression analysis were used to determine difference and regression between two types of dietary calculations, neural networks and WHO's tables. One-sample Kolmogorov-Smirnov test was applied to test the distribution of the data belonged to each parameters. Protein values both calculated from WHO's tables and computed by networks were skewely distributed, therefore Wilcoxon Signed Rank test was used in protein values. Paired samples t -test was used to analyse the difference between two types of calculations for energy and water requirements since data concerning these parameters were normally distributed.

4. RESULTS

The study population was consisted of 312 healthy children, seen at the pediatric outpatient clinics, aged between 1 month- 15 years (mean ± SD, 4.9 ± 4.7 years). The ratio of boys to girls was 160/152.

The mean daily protein requirements of children calculated from WHO's tables and computed with network were 17.6±5.9 g/d and 17.5±6.1 g/d, respectively. The difference in daily protein requirement between two kind of calculations was not significant ($z = -0.53$, $p = 0.60$). The mean daily energy requirements determined by WHO's tables and by network were 1365±502 kcal/d and 1363±500 kcal/d, respectively. The difference was also not significant ($t= 0.11$, $p=0.91$). The calculated daily mean water requirement determined by WHO's tables was 1570±457 ml/d, computed by network was 1566±443 ml/d. The difference in daily water requirements between classical method (depend upon WHO's tables) and ANN method was not significant ($t= 1.2$, $p= 0.31$). The differences of results of protein and water, derived from network and tables, were shown in Figure 2 and Figure 3. The mean and standard deviation of differences in energy requirements between two types of calculations were -0.32± 50.1 kcal/d (data not shown).

The linear regression analysis between two methods of calculations of daily nutritional requirements of energy and water was shown in Figure 4. Significant correlations were found between two methods of calculations of energy ($r= 0.99$, $p<0.001$), water ($r= 0.98$, $p<0.001$) (Figure 4), and protein ($r = 0.99$, $p<0.001$) (data not shown).

4. DISCUSSION

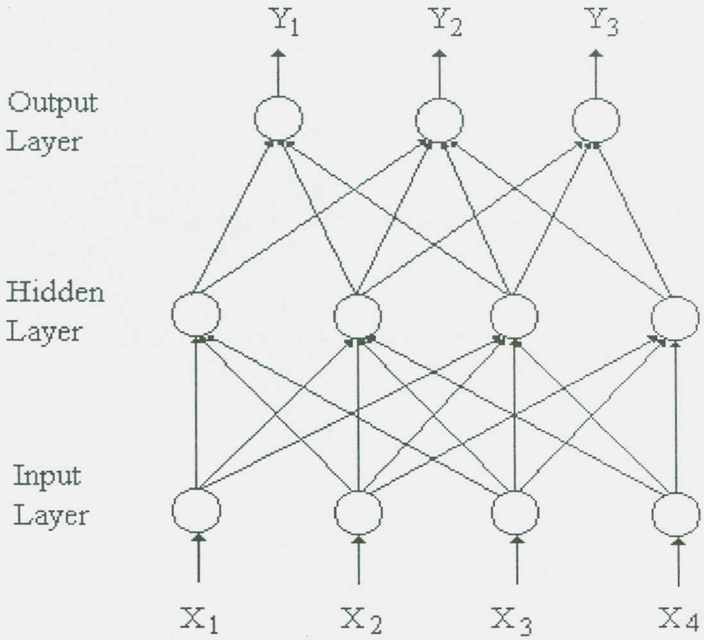
Exclusive breast feeding is sufficient for nutritional requirements of infants until first 4-6 months of life. There is no need to calculate daily energy water and protein intakes of infants adequately breastfeeding. But when mother or infant suffer from any disease preventing sufficient breast feeding, artificial feeding may be necessary. Feeding with infant formula, cow's milk or any other food necessitates calculation of nutritional requirements. Nutritional requirements of a child can be calculated from dietary tables by physicians or dieticians. Due to crowding circumstances of the pediatric clinics, dietary calculations by this classical method may be faulty and this method takes a lot of time. In order to avoid calculation errors and to spare time, we prepared a practical and speedy computer program on neural networks to compute daily energy, protein and water requirements of children not only for definite age or weight but also for every age and weights after neonatal period. Although artificial neural networks have been used extensively for problems in engineering in the last 10 years, they have only recently been applied to medical problems, particularly in the radiology, neurology, genetics, laboratory medicine and cardiology (Itchharporia et al. 1996 and Christy et al. 1995). Dobner et al. (1995) have developed a computer program for calculating parental nutrition of intensive care newborn infants. Though parental nutrition drew attention of pediatricians of newborn subspecialty, any physician that take care of children must have interest in normal oral nutrition. So determination of nutritional requirements for normal children was also beneficial. The difference between two calculated methods of dietary assessment was not significant. We can say that network's assessments are similar that of calculated from WHO's tables. Therefore we can prefer calculation with network in dietary estimations due to accuracy and rapidity of computer program. So physicians and other health workers can save time and avoid calculation errors using network.

In conclusion, we developed a program of neural networks to calculate energy, protein and water requirements of healthy children. This program can be easily adapted to personal computers, and anyone can determine nutritional requirements of children quickly and accurately in outpatient clinics through this program.

5. REFERENCES

1. Barness, L. A. Curran, J. S. (1986). Nutritional requirements. Nelson Textbook of Pediatrics, (Eds. RE Behrman, RM Kliegman, AM Arvin), Saunders Comp., Philadelphia, 141-174.
2. Beksac, M. S. Durak, B. Ozkan, O. Cakar, A. N. Balci, S. Karakus, U. and Laleli, Y. (1995), An artificial intelligent diagnostic system with neural networks to determine genetically disorders and fetal health by using maternal serum markers., Eur J Obstet Gynecol Reprod Biol **59,** 131-136.
3. Christy, P. S. Tervenen, O. Scheithauer, B. W. Forbes, G. S. (1995). Use of a neural network and a multiple regression model to predict histologic grade of astrocytoma from MRI appearances. Neuroradyology **37,** 89-93.
4. Dobner, M. Miksch, S. Horn, W. Popov, C. (1995). VIE-PNN: an expert system for calculating parenteral nutrition of intensive care premature and newborn infants. Wien Kllin Wochenschr. **107,** 128-32.
5. Energy and protein requirements. (1985). WHO Technical Report Series, Geneva **724,** 136-137.
6. Fung, K. S. Chan, F. H. Lam, F. K. Liu, J. G. Poon, P. W. (1996). Visual evoked potential enhancement by an artificial neural network filter. Biomed Mater Eng. **6,** 111-113.
7. Itchharporia, D. Snow, P. B. Almassy, R. J. Oetgen, W. J. (1996). Artificial neural networks: current status in cardiovascular medicine. J Am Coll Cardiol **28,** 515-521.
8. Karlik, B. (1994). The myoelectric control of multifunction prosthesis using artificial neural networks. Ph.D. Thesis. Dep. Elect. Eng., Yildiz Technical University, Istanbul,
9. Naylor, C. J. (1990). Artificial neural network review. University of Nottingham version 1.1, (U.K.)
10. Pao, Y. H. (1989). Adaptive pattern recognition and neural network. Addison-Wesley, Newyork, 130.
11. Place, J. F. Truchaud, A. Ozawa, K. Pardue, H. Schnipelsky, P. (1995). Use of intelligence in analytical systems for the clinical laboratory. Clin Biochem **28,** 373-89.

LEGENDS AND FIGURES



Inputs: X_1 : Age, X_2 : Sex, X_3 :Weight. X_4 : Weight percentile
Outputs: Y_1: Daily protein requirement, Y_2: Daily fluid requirement, Y_3: Daily caloric requirement.

FIGURE 1 Basic structure of multilayer feedforward artificial neural network of this study

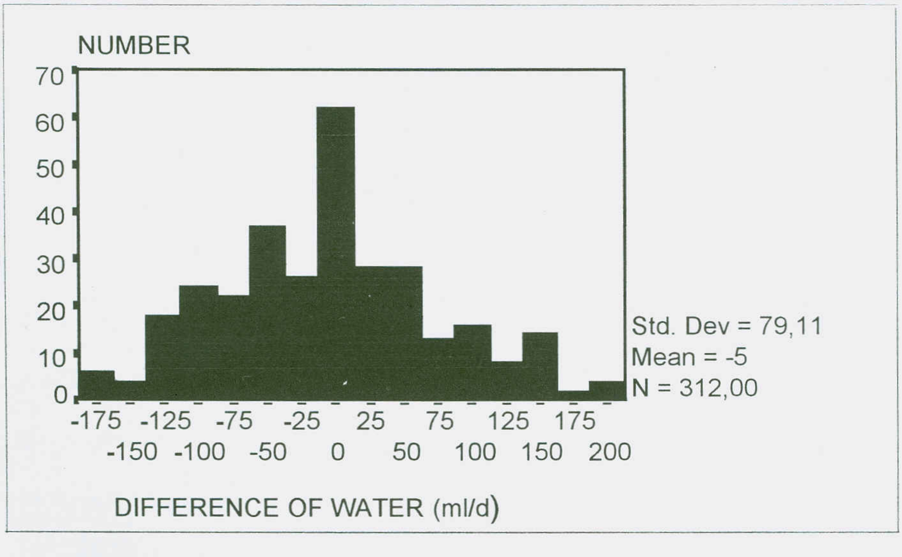


FIGURE 2 The differences between the water values calculated from dietary tables and computed by neural network

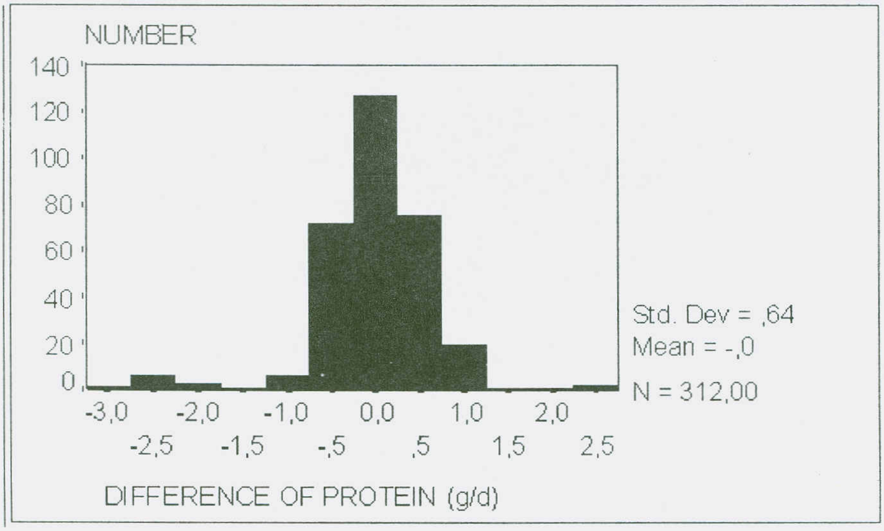


FIGURE 3 The differences between protein values calculated by network and WHO's tables

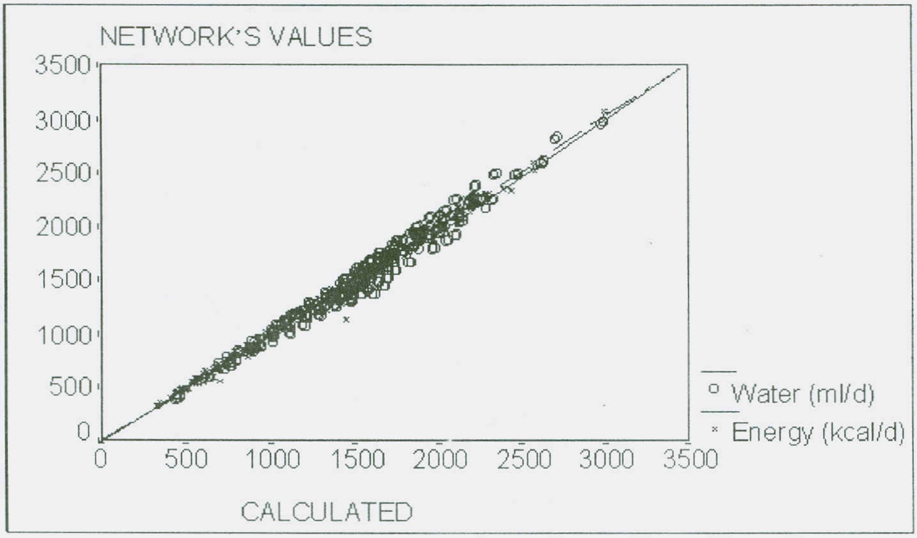


FIGURE 4 The linear regression between two methods of calculation for daily water ($p<0.001$) and energy values ($p<0.001$)