Determination of *WHtR* Limit for Predicting Hyperglycemia in Obese Persons by Using Artificial Neural Networks

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***Abstract* – The abdominal obesity is strongly associated with increased risk of obesity-related cardiometabolic disturbances. The proportion of waist circumference and body height, known as waist-to-height ratio (*WHtR*), has been shown as a good risk indicator related with abdominal obesity. This paper presents a solution based on artificial neural networks (ANN) for determining *WHtR* limit for predicting hyperglycemia in obese persons. ANN inputs are body mass index (*BMI*) and glycemia (*GLY*), and output is weist-to-height ratio (*WHtR*). ANN training and testing are done by dataset that includes 1281 persons.**

***Keywords* – Artificial neural networks, obesity, waist-to-height ratio.**

1. Introduction

Among the main risk factors for coronary heart diseases, including diabetes, hypertension, dyslipidemia, the obesity is of special importance since the increase of fat mass launches a cascade of adipokine-mediated metabolic, inflammatory and haemostasic disturbances accelerating the process of atherosclerosis [1, 2, 3]. In Serbia 54.4% of adult suffers from excessive body mass, while 36.2% of the population is obese [4]. The highest prevalence of overweight and obesity is observed in the region of Vojvodina and is as high as 58.5% [5].

Based on numerous studies provided by many national and international institutions, the body mass index (*BMI*) is widely accepted and used to measure and define the obesity. The values $BMI \geq 25$ kg/m^2 correspond to the overweight, and values $BMI \geq 30$ kg/m^2 correspond to obesity and indicate increased risk of obesity-related adverse health outcomes [3].

The most intensive changes take place inside the visceral fat deposit of the abdomen and that is the reason why the abdominal or central obesity is particularly associated with an increased cardiometabolic risk. [6, 7, 8]. The waist circumference (*WC*) is often used as an effective marker of abdominal visceral fat content and comorbidities associated with obesity [9, 10, 11]. The values $WC \geq 80$ *cm* for women and $WC \geq 94$ *cm* for men indicate increased risk and are widely used in clinical practice. However, individuals with similar waist circumference and different body heights can differ in their health risks [12]. Based on that, the index obtained as a proportion of waist circumference and body height (*WHtR*) has shown to be a better risk indicator and the values $WHtR \geq 0.5$ should indicate increased risk [13, 14, 15].

Hyperglycemia or high blood sugar represents a cardiometabolic risk factor since by increasing oxidative stress and protein glycolization the increased level of glucose accelerates the process of atherosclerosis [16]. Based on [17, 18], the values $GLY \geq 6.1$ *mmol*/*l* indicate increased risk.

In this paper, the multilayer feed-forward ANN with back-propagation as the training algorithm has been applied to determining *WHtR* limit for predicting hyperglycemia in obese persons. Our idea is to train ANN to predict *WHtR* based on *BMI* and *GLY*. We will test various ANN architectures in MATLAB and select an optimal. Then, we will consider *WHtR* value for the limits $BMI = 30$ kg/m^2 and $GLY = 6.1$ *mmol*/*l*.

2. Measurements

The group inquired consisted of 1281 respondents (589 women and 692 men) aged 18 to 67 years, with *BMI* values between 16.60 and 48.00 kg/m^2, *WHtR* values between 0.36 and 0.87 and with *GLY* values between 3.00 and 13.10 *mmol*/*l*. In the Table 1 are shown the minimal, average and maximal values.

	Minimum	Average	Maximum
Age	18	43.67	67
BMI	16.60	29.89	48.00
WHtR	0.36	0.57	0.87
GLY	3.00	5.16	13.10

Table 1. Characteristics of dataset.

The study was conducted in accordance with the Declaration of Helsinki. The respondents volunteered in the study. All the inquires were taken during the morning hours (after the fasted overnight) at the Department of Endocrinology, Diabetes and Metabolic Disorders of the Clinical Centre of Vojvodina in Novi Sad (Serbia).

Body height (*BH*) was measured using Harpenden anthropometer with the precision of 0.1 cm and body mass (*BM*) was measured using balanced beam scale with the precision of 0.1 *kg*. *BMI* is calculated as the ration of body mass (*BM*) and the square of body height (*BH*):

$$BMI\left[kg/m^2\right] = \frac{BM\left[kg\right]}{\left(BH\left[m\right]\right)^2} .$$

Waist circumference (*WC*) was measured using flexible tape with precision 0.1 *cm*, at the level of middle distance between the lowest point on the costal arch and the highest point on the iliac crest. *WHtR* is calculated as the ration of waist circumference (*WC*) and body height (*BH*):

$$WHtR = \frac{WC\left[m\right]}{BH\left[m\right]} .$$

Fasting glucose levels were determined by Dialab glucose GOD-PAP method.

3. ANN System, Results and Discussion

This section presents our solution – ANN system for determining WHtR limit for predicting hyperglycemia in obese persons. The ANN input values are vectors:

$$\overline{X}(i) = \left(BMI(i), GLY(i)\right),$$

while the output values are:

$$Y(i) = WHtR(i),$$

where $i = 1, 2, ..., 1281$.

The optimal number of hidden neurons can be determined using various approaches, but we have used repeated random subsampling validation. The dataset is randomly divided into two parts with the proportion 90:10. The ANN training set is the first part (1153 persons) and the ANN testing set is the second part (128 persons). In the test phase, ANN estimates *WHtR* based on given *BMI* and *GLY* and the estimation accuracy is:

$$AC[\%] = 100\% \left(1 - \frac{\left|WHtR^* - WHtR\right|}{WHtR}\right),$$

where *WHtR* is the exact value and $WHtR^*$ is the value estimated by ANN. Various architectures with one hidden layer and 1-5 hidden neurons (N_h = 1, 2, 3, 4, 5) were trained and tested 100 times. The average accuracy *AC* and standard deviation *SD* were calculated. The trained ANN was tested first on the known data (training set) and the obtained results are given in Table 2.

N_h	AC_{TR}	SD_{TR}
1	94.3385	0.0022
2	94.3745	0.0030
3	94.3810	0.0030
4	94.3985	0.0018
5	94.4319	0.0037

Table 2. The average accuracy AC_{TR} and standard deviation SD_{TR} on the training set.

After that, trained ANN was tested on the unknown data (testing set) and the obtained results are given in Table 3.

N_h	AC_{TS}	SD_{TS}
1	94.3903	0.1879
2	94.3261	0.2077
3	94.3495	0.3719
4	94.2825	0.1508
5	94.1908	0.1798

Table 3. The average accuracy AC_{TS} and standard deviation SD_{TS} on the testing set.

After every testing, given ANN architecture was asked to estimate *WHtR* value for the limits *BMI* = 30 kg/m^2 and *GLY* = 6.1 *mmol/l*. The average estimated *WHtR* values are given in the Table 4.

N_h	*WHtR*
1	0.5781
2	0.5802
3	0.5816
4	0.5829
5	0.5824

Table 4. The average estimated *WHtR* values.

Comparing results from Table 3, we conclude that the single-layered ANN architecture with 1 hidden neuron provides the best results (maximal average accuracy with standard deviation as small as possible), so it is accepted as the optimum and depicted on the Figure 1. From Table 4, the value 0.5781 is *WHtR* limit for predicting hyperglycemia in obese persons.

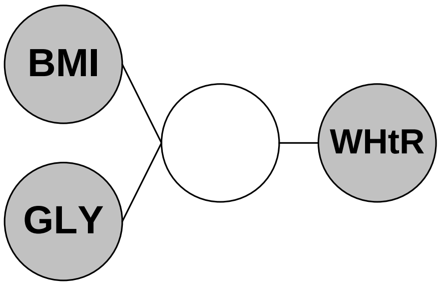

Figure 1. The optimal ANN architecture.

4. Conclusion

In this paper, we have presented an ANN solution for determining *WHtR* limit for predicting hyperglycemia in obese persons. Based on our results, if an obese person ($BMI \geq 30$ kg/m^2) has $WHtR \geq 0.5781$ then she/he has increased risk of hyperglycemia ($GLY \geq 6.1$ $mmol/l$). This approach could be a useful tool in both, individual and public health prevention since it can select persons with increased risk of hyperglycemia in an easy, non-invasive and cheap way.

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