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ABOUT A POSSIBILITY OF PREDICTING THE CONTRAST SENSITIVITY THROUGH INTENSE PHYSICAL EFFORT IN DIABETIC RETINOPATHY

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Abstract. *The present work makes a comparison between the sensitivity to contrast in the case of people with and without diabetic retinopathy, but who perform physical effort or not by walking alertly in the Nordic style. The differences between the two types of state, at rest or systematic movement, were extrapolated, in order to predict the evolution of this quality of human vision. The objective pursued consisted in obtaining relevant arguments for the promotion of current health strategies through sports. The psychophysical tests used to determine contrast sensitivity were supplemented with those which determine the variation in retinal thickness measured by computerized optical tomography.*

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Keywords: contrast sensitivity, Nordic walking, diabetic retinopathy.

1. Introduction

A major problem currently faced by a large part of the world's population is the alarming increase in the incidence of diabetes [1]: over 11% of the population and over 20% of the elderly over 55 suffer from diabetes (DM). Among the significant consequences of incorrect management of this disease, the following stand out, with priority:

- retinopathies, with a decrease in image quality (by decreasing visual acuity and worsening contrast sensitivity in the observed images); diabetic retinopathy is a general term that refers to all disorders of the retina, in the case of diabetes;
- obesity, as a result of inadequate nutrition and excessive sedentarism.

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One of the methods to improve the above consequences is based on increasing the duration and intensity of daily physical effort. It is known that the lack of physical effort and obesity contribute, over time, to the decrease in the quality of vision. Thus, in the paper [2] the authors found a consistently strong correlation between obesity and the development of four major eye diseases that may cause blindness, as age-related macular degeneration (AMD), cataract, glaucoma and diabetic retinopathy [2].

Current studies, such as [3], have shown that the link between obesity and these eye diseases is probably due to the increased risk of peripheral arterial disease. The above study also shows that underweight, overweight and obese participants had the highest risk of vision impairment compared to normal weight participants.

The present work addresses some possibilities of evaluating the visual sensitivity to contrast during intense physical effort (through alert walking in Nordic style) compared to the state of relaxation (stationary) with and without diabetic retinopathy. The authors followed the brief analysis of the decrease in the quality of vision (contrast sensitivity and visual acuity), in the short term/evolutionary in diabetic retinopathy, without and with intense physical effort (by alert walking in Nordic style). Nordic walking is a style of walking, alert, but which requires the mobilization of all muscle groups of the whole body, by using a specific equipment (walking poles, see fig.1, after [2]. This style of walking burns with 18% more calories, and the overtaking speed is 25% higher than during normal walking [2]. Nordic walking accelerates the metabolism and the cardiovascular system of the one who practices it. Figure 1 shows some images of the method of use of this equipment, the image in fig.1 (right) being of one of the co-authors of this work, image also presented in a previous article [4].

Figure 1. Some images that highlight the use of the equipment for the Nordic walking style

2. Contrast sensitivity assessment methods

It is known that the visual sensitivity is dependent on visual acuity (the ability to identify different black/colour symbols on a white background). So, the visual acuity determines the sharpness of human vision from a distance, and the contrast sensitivity refers to the ability to differentiate between an object and its background (fig.2). Contrast sensitivity is also more sensitive than visual acuity, which makes monitoring it potentially more important.

Figure 2. The amount of contrast in some versions [5]

In addition, visual acuity decreases as the thickness of the macula of the human eye decreases [6]. Daily variations of visual acuity disturbances are produced by retinal degeneration, which produces variations in ocular refraction. In the case of patients with diabetes, contrast sensitivity is significantly influenced by glycemia, see fig.3 [7]). The best-fit function returns the following parameters: peak contrast sensitivity, CS_p = 2.22 log units(corresponds to 166); spatial frequency at which peak contrast sensitivity occurs, SF_p = 0.4 log c/deg (corresponds to 2.5 c/deg); $width_L$= 0.68 and $width_R$= 1.28.

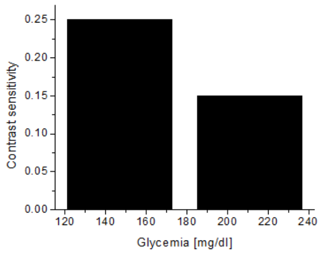

Figure 3. Example of contrast sensitivity values of a 68-year-old diabetic patient, depending on glycemia

In principle, there are two current ways of evaluating visual sensitivity to contrast, namely:

❖ Direct evaluation, through psycho-physical vision tests, e.g. Pelli Robson (fig.4). In the example from fig.4 (see table 1, also), the value 2.0 (log 100=2) indicates a very good contrast sensitivity. Threshold contrast ($C_{threshold}$) is the lowest contrast needed to see a group of 3 letters. Contrast sensitivity (CS) is, according to [8], the inverse of threshold contrast ($CS=1/C_{threshold}$). Many a time, the contrast is measured as percentage [9], the proportion multiplying by 100; so, for example, if the lowest perceived contrast $C_{threshold}$ is 3%, the contrast sensitivity CS will be 1/0.03 =0.33 and log 33=1.5. Normal contrast sensitivity is above 1.5 on the logarithmic scale (33 letters observed).

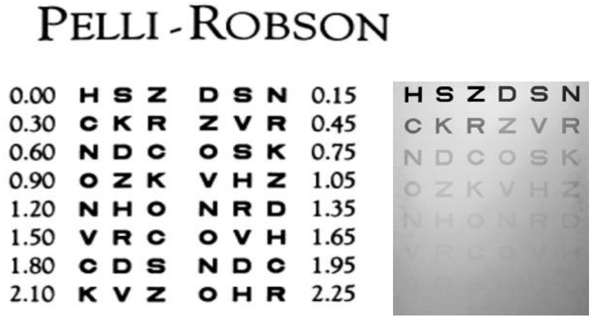

Figure 4. Example of Pelli-Robson psycho-physical test

Table 1 Some correlations between the nominal value and the related logarithm for contrast sensitivity (CS)

$C_{threshold}$ [%]	CS [%] = $100/C_{threshold}$	Log CS
25	4	0.60
10	10	1.00
6.25	16	1.20
5	20	1.30
3.12	**32**	**1.50**
2.5	40	1.60
1.58	63	1.80
1.25	80	1.90
1	100	2.00
0.8	125	2.09
0.6	166	2.22

❖ Indirect evaluation, by determining the macular thickness, using optical coherence tomography (OCT), allowing visualization of the retina in the form of cross sections and measuring its thickness, similar to classic ultrasound (fig.5).

A simulation of the functional structure of the human eye with a camera, in which the lens and retina can be assimilated with the objective, respectively the detection matrix is presented in fig.6 and 7, using the software MAVIISS 1.5 [10].

In this simulation, in which the MTF is comparable to the contrast sensitivity, it is observed that it is strictly dependent on the visual acuity [lp/mm] on the abscissa as can seen in the paper [7].

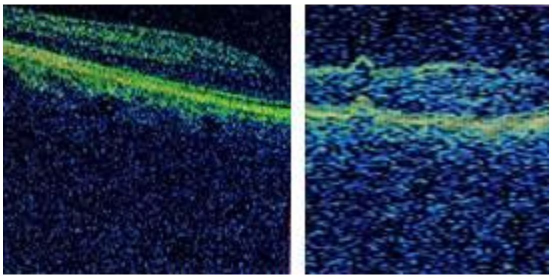

Figure 5. Images of the retinal thickness (for the case of two glycemia)

In his paper [11], Denis G. Pelli says that the modulation transfer function (MTF) indicates the ability of an optical system to reproduce (transfer) various levels of detail (spatial frequencies) from the object to the image. It is the optical contribution to the contrast sensitivity function (CSF). MTF has the advantage that it can highlight the influence brought by its main optical components: the crystallin, the aqueous humor and the retina, based on the similarity between a camera and the eye [12,13]. A plot of CS over a range of spatial frequencies gives the contrast sensitivity function [7].

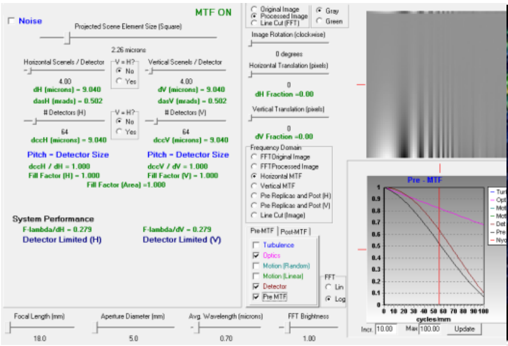

Figure 6. A possibility to simulate MTF with MAVIISS 1.5 software

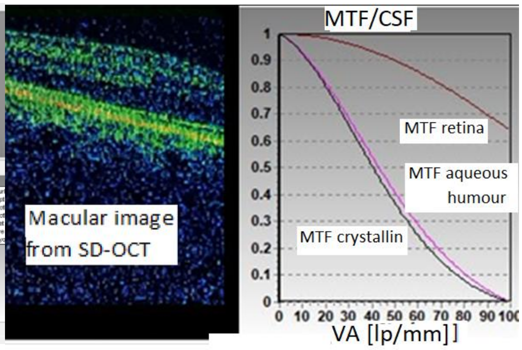

Figure 7. MTF or CS variation can be plotted with MAVIISS 1.5 software

For example, for a 68-year-old diabetic patient, whose glycemia was 147 at 9 a.m. and 211 at 3 p.m., the measurements with the Pelli test indicated the contrast sensitivities of 0.25 and 0.15 (on the logarithmic scale), respectively (fig.8).

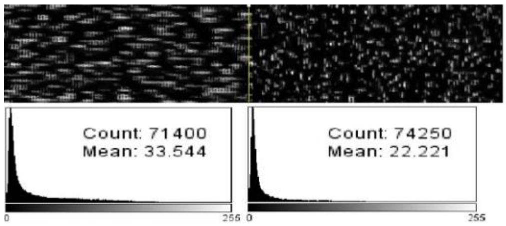

Figure 8. A sequence of the photoreceptor cells in the retina for the case of the two glycemia, of 147 and 211 respectively.

3. Contrast sensitivity assessment methods

The present study is based on the analysis of data on sensitivity to contrast of a group of patients (with and without diabetes), as well as of a participant who practiced, for several days in a row, the alert style of Nordic walk (see table 1).

Table 2 The data measured every day while traveling the route

Day while traveling the route	No.walk stage	The period of a walk [hour]	Pulse [bmp] during the walk	Traveled distance [km]
Day 1	Walk 1	9.51 -10.19	70-80	2.67
	Walk 2	10.21-10.52	80-81	2.66
Day 2	Walk 1	9.53-10.17	78-92	2.66
	Walk 2	10.23-10.52	89-91	2.66
Day 3	Walk 1	12.18-12.47	70-93	2.71
	Walk 2	12.49-13.17	93-98	2.66
Day 4	Walk 1	10.36-11.05	88-89	2.61
	Walk 2	11.24-11.52	91-92	2.68
Day 5	Walk 1	10.20-10.49	84-85	2.66
	Walk 2	10.52-11.20	87-88	2.64
Day 6	Walk 1	15.01-15.31	90-93	2.62
	Walk 2	15.40-16.05	86-87	2.02
Day 7	Walk 1	12.36-13.06	90-91	2.79
	Walk 2	13.37-14.07	95-96	2.74
Day 8	Walk 1	15.29-15.57	91-92	2.68
	Walk 2	15.58-16.25	96-97	2.63
Day 9	Walk 1	10.33-10.57	87-88	2.26
	Walk 2	10.59-11.32	91-92	2.96

So:

❖ The group of patients was monitored with OCT throughout one day, with specifying that all patients followed, during the monitoring, treatment with oral antidiabetics or insulin. The aforementioned analysis was based on OCT images from patients with variable glycemia levels determined over the course of a day. It is mentioned that patients who had diabetes followed drug treatment recommended;

❖ Completion (in several walking stages, repeated, the same route, in regime of intense physical effort (Nordic walking style) was done by co-author no. 2 of this article, which determined the sensitivity to contrast by the direct method, with the visualization of the Pelli Robson test at different brightnesses of the screen of a smartphone (on which the test in question was displayed) and in different stages of the traveled route.

4. Interpretation of the results

The data of the measurements made, converted into graphs, are presented in the figures below, as follows:

4.1 For steady state:

- The variation of glycemia during the time for the patients with and without diabetes (fig. 9);
- The variation of contrast sensitivity, over time, during one day of monitoring, for the patients with and without diabetes (fig. 10). From fig. 10 on can see that the variation of CS with glycemia level is relatively small in the interval 100-240 mg/dl.

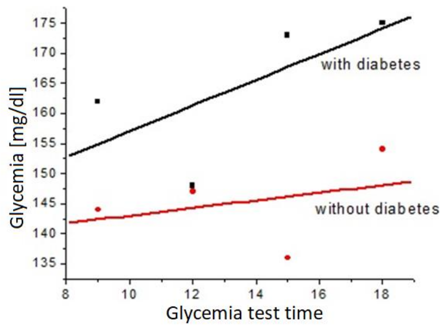

Figure 9. The variation of glycaemia throughout the day, during the test hours

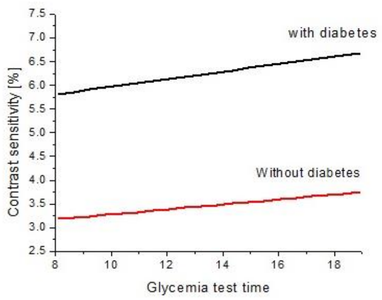

Figure 10. The variation of the contrast sensitivity throughout the day, during the test hours

- The variation of the contrast sensitivity with glycemia for the patients with and without diabetes (fig. 11);
- The variation of glycemia throughout the day (fig. 12);
- The variation of macular thickness depending on glycemia (fig**.** 13);
- The contrast sensitivity variation depending on the thickness of the fovea (see fig. 14);

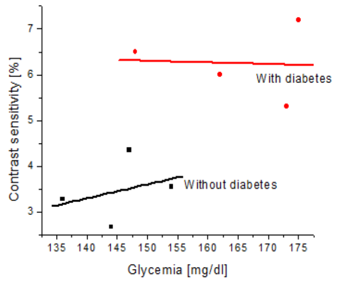

Figure 11. The variation of the contrast sensitivity with the glycemia.

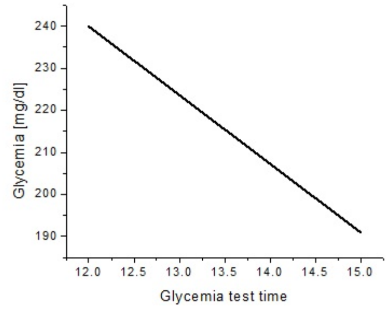

Figure 12. The variation of the glycemia throughout the day, during the test hours

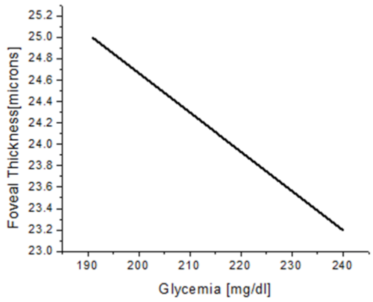

Figure 13. The variation of the foveea thickness with the glycaemia

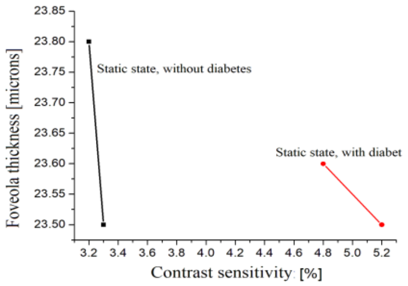

Figure 14. The variation of the fovea thickness with the contrast sensitivity for the patients wit hand without diabetes, stationary state

4.2 For the dynamic mode, walking in Nordic style

- The variation of contrast sensitivity, depending on the brightness of the test (fig. 15);
- The pulse variation (fig. 16);

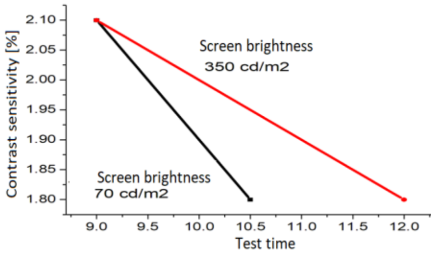

Figure 15. The variation of contrast sensitivity for two distinct screen brightness of the smartphone used for Pelli Robson test

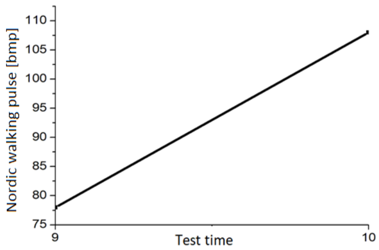

Figure 16. The pulse during the traveled distance

- Comparison between the variation of contrast sensitivity in static, respectively dynamic mode, with the estimation of the prediction of the evolution of this sensitivity, in people with diabetic retinopathy and who practice sustained physical effort over time (fig. 17).

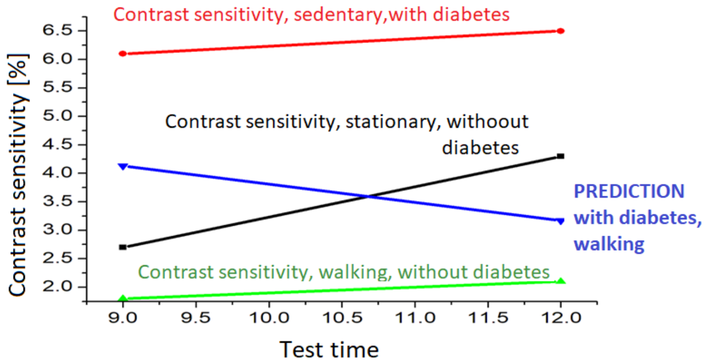

Figure 17. A possibility of predicting the contrast sensitivity through intense physical effort in diabetic retinopathy

The results from fig.17 are similary to the conclusions from the paper [14], where the authors concluded the importance of physical activity versus physical inactivity in relation to eyesight.

5. Conclusions

(1) Because the speed and pulse are much higher, the Nordic walking style ensures a much higher energy consumption, compared to the classic alert walking;

(2) Contrast sensitivity of people who practice intense physical effort is much better, over time, than in people who have a sedentary state. It is appreciated that the danger of macular degeneration is also reduced;

(3) OCT and ontrast sensitivity varies in diabetic patients depending on glycemia. Contrast sensitivity decreases with increasing of glycaemia, but retinal thickness in the fovea decreases particularly at glycaemia values greater than 180;

(4) There is the possibility of predicting the evaluation of the evolution of visual acuity in people with diabetic retinopathy and who systematically practice alert walking.

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