ORIGINAL ARTICLE

Selected diabetes control indicators and working memory efficacy

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Abstract

OBJECTIVES: The goal of the study was an evaluation of differences in working memory effectiveness between patients with type 1 and type 2DM. It was also attempted to ascertain whether the level of diabetes control is associated with working memory effectiveness.

METHODS: 62 subjects were enrolled into the study. All patients were divided into two groups: patients with type 1DM (n=31) and with type 2DM (n=31). The Trail Making Test (TMT) and the Stroop Test were used for evaluation of working memory effectiveness. Diabetes control indicators included: glycated haemoglobin (HbA_{1C}) level, total cholesterol concentration, HDL and LDL cholesterol concentration and body mass index (*BMI*).

RESULTS: The patients with type 1DM obtained a significantly lower time in the execution of TMT, part B (p=0.01) and of RCNb (p=0.01) and NCWd (p=0.01) versions of the Stroop Test, while making significantly less errors in NCWd version (p=0.01). Significant correlations were demonstrated between BMI values and the rate of execution of TMT, part B (p=0.03), as well as the rate of execution of RCNb (p=0.04) and NCWd (p=0.01) versions of the Stroop Test. Total cholesterol level was significantly correlated with the rate of execution of TMT, part A (p=0.04) and B (p=0.01). No significant correlations were found between cholesterol fraction levels in blood of the studied patients and the results of performed tests, with one exception, regarding the relationship between LDL cholesterol fraction and the rate of the Stroop Test execution in RCNb version (p=0.04).

CONCLUSIONS: 1). Higher working memory efficacy was demonstrated among the patients with type 1DM vs. those with type 2DM. 2). The level of diabetes control is an influential factor for working memory effectiveness in diabetic patients.

Abbreviations:

DM	- diabetes mellitus
TMT	- Trail Making Test
RCNb	- reading colour names in black
NCWd	- naming colour of word – different
HbA_{1C}	- glycated haemoglobin
HDL	- high density lipoproteins cholesterol
LDL	- low density lipoproteins cholesterol
BMI	- body mass index

INTRODUCTION

The worldwide prevalence of diabetes is projected to rise from 2.8% for the year 2000 up to 4.4% for 2030, increasing the number of individuals with diabetes from 171 to 366 million and indicating an ongoing global epidemic of diabetes mellitus (Lindahl *et al.* 2010). In the USA, one (1), out of five (5) inhabitants after 65, falls ill with diabetes mellitus, while the incidence its clinical symptoms amounts to 10% in the entire population of subjects above 65 (Jack *et al.* 2004). DM occupies now the 4th position in the ranking of the frequency of patient contacts with doctor and is a serious cause of preliminary loss of ability to work and of increased mortality rates. It may lead to disability and expected life-span reductions, first of all, in consequence of chronic complications (Jack *et al.* 2004). Psychiatric consequences of diabetes mellitus are more and more often the subject of undertaken research (Khuwaja *et al.* 2010). In particular, the influence of the disease on the cognitive functionality of affected patients is a very interesting issue. Gaining a more detailed knowledge on that issue, being also the subject of the reported study, is not only significant from the medical or psychological point of view but it may be of huge importance for diabetic patients themselves, regarding the possibility to improve the quality of their life.

Working memory is one of the cognitive functions, which demonstrates significant deterioration among patients with diagnosed diabetes mellitus. It is short-term memory with short-time storage of data and criteria, allowing us to execute current tasks and perform current actions. Working memory has been drawing much interest and attention during the recent years, taking into account its significant role for the proper course and integration of executive functions, i.e., complex cognitive processes, such as planning, conceptual thinking, problem solution, terrain orientation and decision taking, as well as for the awareness of subject's relationships with the environment and for his/her social and adaptive behaviours (Lukowski *et al.* 2010; Pukrop & Klosterkötter 2010). Dysfunctions of working memory and of executive functions are, first of all, associated with disturbed functionality of the anterior cortical region of the brain, i.e., the, so-called, prefrontal cortex (Barch *et al.* 2003; Karlsgodt *et al.* 2006). Depending on the character of undertaken tasks (involving the spatial-visual working memory – the right cerebral hemisphere – or the verbal working memory – the left cerebral hemisphere – definite areas of the prefrontal cortex are activated (mainly the dorsolateral region). The frontal lobes ensure normal course and synthesis of free and conscious actions, undertaken at all the levels of activity organisation (Mok *et al.* 2010). Beside working memory, the other cognitive functions, deteriorated by diabetes mellitus, include: the ability of abstract thinking, planning, task initiation and solution, visual-spatial skills, solution of arithmetic problems, the ability of using feed-back information about committed errors, behaviour control and speech fluency. This group of patients is also characterised by other common features, such as compromised flexibility in undertaken actions, difficulties in planning and execution of expedient behaviours, as well as perseverations and numerous stereotype behaviours (Andersson *et al.* 2009; Filoteo *et al.* 2010).

It has for long been known that diabetic subjects earlier reveal the symptoms of ageing process, the course of which is then also more rapid (it also concerns the cognitive functions) (Wu *et al.* 2002). Taking into consideration the entire population of diabetic patients, the risk groups associated with deterioration of cognitive functions include patients after 65 and children (Northam *et al.* 2001). Cognitive deficits in the former group are often paralleled by cardiovascular diseases (Fontbonne *et al.* 2001; Biessels *et al.* 2007). It appears from the studies by Strachan *et al.* (2000) that diabetic patients more often demonstrate disturbances of cognitive functions when compared with age-matched subjects without metabolic disorders. Also regarding the population of patients with abnormal glucose tolerance and with an increased risk for type 2 diabetes in future, an elevated prevalence of deteriorated cognitive capacity was observed (Vanhanen *et al.* 1998). Mutual correlations between diabetes and dementia are more and more often the subject of discussions among researchers (diabetes mellitus doubles the risk for dementia, both angiogenic and that, induced by Alzheimer's disease (Arvanitakis *et al.* 2004). The possible causal mechanisms of dementia in diabetic patients remain hypothetical, while MRI studies have so far shown varying degrees of cortical atrophy, cerebral infarcts and deep white matter lesions (Barrou *et al.* 2008). Chronic hyperglycaemia and hyperinsulinaemia primarily stimulate the formation of Advanced Glycation Endproducts (AGEs), which leads to an overproduction of Reactive Oxygen Species (ROS). Protein glycation and increased oxidative stress are the two main mechanisms involved in biological ageing. Too much insulin in the brain may be associated with reduced amyloid-beta (Abeta) clearance, due to the competition for their common and main depurative mechanism – the Insulin-Degrading Enzyme (IDE). Since IDE is much more selective for insulin than for Abeta, brain hyperinsulinism may deprive Abeta of its main clearance mechanism. Hyperglycaemia and hyperinsulinaemia seem to accelerate brain ageing also by inducing tau hyperphosphorylation and amyloid oligomerisation, as well as by leading to widespread brain microangiopathy. In fact, diabetic subjects are more likely to develop extensive and earlier-than-usual leukoaraiosis (White Matter High-Intensity Lesions – WMHL) (Roriz-Filho *et al.* 2009).

The goal of the reported study was an evaluation of the differences in working memory effectiveness between patients with type 1 diabetes mellitus and those with type 2 of the disease. Increased cognitive

deficits, regarding working memory and executive functions may affect the functioning and social adaptability of diabetic patients. Those disturbances impair then the patient's ability to cope with everyday, specific situations in social environment, mainly by deteriorating his/her capacity to solve problems and reducing the energies to acquire new skills and meet new challenges.

MATERIAL AND METHODS

Sixty-two (62) subjects (men: *n*=31, 50.0%) participated in the study, their age ranging from 18 to 55 years. The mean age for all the studied subjects was 42.42 years, *SD*=10.78. All the studied patients were divided into two groups: patients with type 1 diabetes and those with type 2 of the disease. Education was measured by the number of years of completed education (years at school). Considering the characteristic features of the Polish education system, the education period ≤ 9 yrs was considered primary education, 10–12 yrs - secondary and > 12 yrs – higher education. The average time of diabetes treatment in both types of diabetes mellitus was: 13.21 years, *SD*=10.92 for the whole group. The mean value of glycated haemoglobin (HbA_{1C}) in both groups of the diabetic patients together was 9.47, *SD*=2.69. Whole venous blood was collected for HbA_{1C} measurements. Collected samples were processed within the first 24 hours. High-Performance Liquid Chromatography (HPLC) was applied for the measurements in question. No statistically significant differences were observed between the patients of either group, regarding the disease duration or the mean value of HbA_{1C} (p>0.05). See Table 1 for demographic characteristics of the study group and for recorded data of disease course.

The patients with diagnosed type 1 and type 2 diabetes mellitus had been treated at the Department of Diabetology and Metabolic Diseases, Medical University in Łódź. The qualification of study subjects into the group of patients, treated either for diabetes mellitus of type 1 or that of type 2, was based on the diagnostic criteria, contained in ICD-10 (1993) and the criteria of the Polish Diabetological Society 2010 (2010). The subjects with disorders from the 1st and the 2nd axis were excluded from participation in the study. Each of the participants provided a written consent to take part in the study, according to the protocol, approved by the Bioethical Commission at the Medical University in Łódź (Decision No. RNN/356/06/KB of October 24, 2006).

Method

The Trail Making Test (TMT) and the Stroop Colour Word Interference Test (Stroop Test) were employed in the study. The former one consisting of two parts: A and B. In part A, the examined subject has to connect points with numbers from 1 to 25 with a continuous line and as quickly as possible. In the second phase (part B), the examined patient has to alternately connect the points marked with digits with the points marked with subsequent letters of the alphabet, following the pattern: 1-A-2-B-3-C-4-D, etc. The test score is the time, measured in seconds in part A and in part B. In TMT, part A, the psychomotor rate and the efficiency of visual-motor coordination are studied, while part B, beside the above-mentioned evaluations, is used to assess the visual-spatial working memory and the ability of switching to a new action criterion, having learned one principle of reaction (Alexander *et al.* 2005; Sánchez-Cubillo *et al.* 2009).

The Stroop Test was performed with the use of paper cards. Since the test does not have its Polish adapted version, the authors used cards, which they had designed by themselves, following the patterns available in literature (Stroop 1935). The test is used for verbal working memory evaluations. The test performance level depends on efficient attention functions (concentration, selectivity). Its results provide information, regarding cognitive flexibility and suppression of impulsive, automatised reaction. The Stroop Test consists of two parts: RCNb (*reading colour names in black* – an examined person has to read as quickly as possible 10 rows of words, with 5 words in each row, designating the names of colours and printed in black on a white sheet of paper) and NCWd *(naming colour of word – different* – an examined person has to name as quickly as possible the colours of print of particular words, where the colour of print does not correspond to the colour it designates). The test score includes the time periods, obtained in the first and in the second phase. NCWd part of the Stroop Test is used to assess the verbal efficacy of working memory, the executive functions and the efficiency of attention processes (Audenaert *et al.* 2001). In the reported study, the performance (time), obtained during the execution of each part, was evaluated with the number of errors, made in both parts together (Stroop 1935; Vendrell *et al.* 2005; Spapé & Hommel 2008).

Prior to TMT and the Stroop Test, no evaluation of intellectual capacity was performed in either of the studied patients. However, based on available medical records and obtained histories, no case of intellectual capacity below standard level was identified in any of the study participants.

In order to evaluate diabetes control, the following factors were taken into account: glycolysed haemoglobin level (HbA_{1C}), total cholesterol concentration, HDL (high density lipoproteins cholesterol) and LDL (low density lipoproteins cholesterol) cholesterol concentration, Body Mass Index (BMI, kg/m^2). The term „diabetes control" is to be understood as the degree of approximation of the studied metabolic process control indicators to their physiological levels, with a simultaneous absence of any adverse effects of administered drugs or treatment methods. In case of effective therapy, the degree of approximation should be very high

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Tab. 1. Demographic characteristics of the group with type 1 diabetes vs. the group with type 2 diabetes.

			Diabetes of type 1 *n*=31			Diabetes of type 2 *n*=31		
			n	%	(±SD)	n	%	(±SD)
Gender		Female	23	74.49	–	23	74.49	–
		Male	8	25.51	–	8	25.51	–
Age in years		–	–	–	38.10 (±11.64)	–	–	44.95 (±10.11)
Education		Primary	6	18.75	–	13	41.94	–
		Secondary	19	61.29	–	14	45.16	–
		High	6	19.35	–	4	12.91	–
Education period in years		–	–	–	11.66 (±2.73)	–	–	12.32 (1.87)
Disease markers		Disease duration in years	–	–	14.67 (±9.05)	–	–	15.83 (7.81)
	HbA_{1C}		–	–	9.17 (±1.46)	–	–	9.78 (3.56)
	BMI	27–40 Obesity	3	9.68	–	21	67.74	–
		25–27 Overweight	12	38.71	–	3	9.68	–
		20–25 Normal body weight	11	35.48	–	6	19.35	–
		18–20 Body weight deficiency	5	16.13	–	1	3.23	–
		< 18 Malnutrition	–	–	–	–	–	–
	Total cholesterol level	<175 mg/dl	12	38.71	–	12	38.71	–
		175–200 mg/dl	6	19.35	–	6	19.35	–
		200–239 mg/dl	6	19.35	–	4	12.91	–
		>240 mg/dl	7	22.58	–	9	29.03	–
	LDL	<100 mg/dl	11	35.48	–	11	35.48	–
		100–150 mg/dl	13	41.93	–	10	32.25	–
		150–190 mg/dl	4	12.91	–	7	22.58	–
		>190 mg/dl	3	9.68	–	3	9.68	–
	HDL	>55 mg/dl	5	16.13	–	5	16.13	
		35–55 mg/dl	16	51.61	–	16	51.61	
		<35 mg/dl	10	32.26	–	10	32.26	

n – number of patients; % - percentage of patients; (±SD) – standard deviation; $HbA1_C$ - Value rate of glycated haemoglobin; BMI - Body Mass Index; HDL - high density lipoproteins cholesterol; LDL - low density lipoproteins cholesterol.

(Sieradzki 2006; Orłowska-Kunikowska 2010). Recommendations of the Polish Diabetological Society 2010 (2010) were accepted in the reported study, regarding the criteria for carbohydrate and lipid metabolism control in diabetic patients.

Statistics

The methods of descriptive statistics and statistic inference were used in the statistical analysis of obtained results. The normality of distribution of the studied variables was checked by the Kolmogorov-Smirnov test. The t-test value turned out statistically insignificant, providing no foundations to discard the hypothesis of distribution normality.

The relationship of particular diabetes control indicators with the performance level, obtained in the TMT or the Stroop Test, was evaluated on the basis of Spearman's rank correlation coefficient (Spearman's ρ). Dif-

ferences in performance levels, observed in the TMT and the Stroop Test, were evaluated in both study groups by the Student t-test. In all the applied statistical methods, $p<0.05$ was regarded as the level of significance.

RESULTS

Table 2 presents the differences in performance levels, obtained in the TMT and the Stroop Test by the patients with type 2 and type 1 diabetes mellitus.

The patients with type 1 diabetes obtained, on the average, a significantly shorter time of TMT part B performance (p=0.01). The patients with type 1 diabetes demonstrated a significantly shorter time of performance in RCNb (p=0.01) and NCWd (p=0.01) of the Stroop Test and made significantly less errors in NCWd part (p=0.01) of the test vs. the patients with type 2 diabetes.

Tables 3 and 4 present Spearman's ρ correlation coefficient values for the performed tests, as well as other diabetes control indicators.

A statistical analysis demonstrated the occurrence of significant correlations between BMI values and TMT, part B performance rate (a negative correlation) and the performance rate of the Stroop Test, RCNb and NCWd. Total cholesterol level was significantly correlated with the performance rate of TMT, parts A and B.

The statistical analysis with the use of Spearman's ρ correlation coefficient did not reveal any significant correlations between cholesterol fraction level in blood of the studied patients and the results of the tests, presented in the tables above. The only observed relationship was that between LDL cholesterol fraction and the performance rate of the Stroop Test in RCNb part.

DISCUSSION

The studied patients with type 1 diabetes mellitus obtained better results in the tests evaluating the working memory efficacy vs. those with type 2 diabetes (see Table 2). A number of authors point to the occurrence of deeper cognitive deficits among patients with type 2 diabetes vs. those with type 1 of the disease (Kwiatkowska *et al.* 2005; Arvanitakis *et al.* 2006; Manschot *et al.* 2006; Pasquier 2006). In the latter case, attention is often paid to the general decrease of cognitive abilities only (Kumari *et al.* 2000), which are reversible in character and which may result from numerous hypoglycaemia (Wysocki *et al.* 2003; Brands *et al.* 2006). Ryan & Geckie (2000) and Jacobson *et al.* (2007) mention merely certain deteriorations, regarding performance and psychomotor efficacy in this group of patients. In such cases, it may be a positive insulin effect on the cognitive functioning of studied subjects, what has been emphasised in foreign reports (Kern *et al.* 2001). However, Sommerfield *et al.* (2003) observed decreased visual-spatial efficacy of working memory (using TMT) in patients with type 1 diabetes mellitus. Memory system, examined in the reported study, was significantly affected by acute hypoglycaemia. More serious deficits of cognitive functions in the group of patients with type 2 DM may be caused by a few factors. First, in that group of patients, an increased risk for micro- and macroangiopathic complications is observed, what may provide a feedback, negatively affecting the cognitive abilities of the patients (Hanon 2005). Delayed identification of carbohydrate metabolism and therapy onset only at the level of fully developed disease may certainly contribute to dissatisfying therapeutic outcomes in this group of patients (Kurzawa *et al.* 2004). Moreover, the risk fac-

Tab. 2. Mean standard deviations and significance levels of differences for particular study groups.

Variable	Diabetes of type 1			Diabetes of type 2			t	*p*-value
	(±SD)	Min.	Max.	(±SD)	Min.	Max.		
TMT part A time (sec.)	34.68 (±23.06)	14.00	102.00	44.42 (±30.12)	20.00	148.00	–1.43	0.16
TMT part B time (sec.)	70.94 (±31.75)	35.00	166.00	101.94 (±57.86)	40.00	307.00	–2.62	0.01*
Stroop Test RCNb, time (sec.)	21.58 (±3.92)	16.00	32.00	27.09 (±10.71)	16.00	61.00	–2.69	0.01*
Stroop Test RCNb the number of errors	0.16 (±0.89)	0.00	5.00	0.32 (±0.65)	0.00	3.00	–0.81	0.42
Stroop Test NCWd time (sec.)	52.68 (±11.61)	38.00	103.00	65.23 (±15.97)	42.00	120.00	–3.54	0.01*
Stroop Test NCWd the number of errors	2.23 (±3.92)	11.00	3.02	4.58 (±4.11)	0.00	17.00	–2.57	0.01*

TMT – Trail Making Test; (±SD) – standard deviation; *p statistically significant.

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Tab. 3. Spearman's ρ correlation coefficients for BMI and total cholesterol levels and for the performed tests.

Variable	BMI		Cholesterol level	
	Spearman's ρ	*p*-value	Spearman's ρ	*p*-value
TMT part A – time (sec.)	–0.19	0.13	0.25	0.04*
TMT part B – time (sec.)	–0.27	0.03*	0.29	0.01*
Stroop Test, RCNb, time (sec.)	–0.21	0.04*	0.11	0.27
Stroop Test, RCNb – the number of errors	0.14	0.28	0.69	0.48
Stroop Test, NCWd – time (sec.)	–0.32	0.01*	0.69	0.49
Stroop Test, NCWd – the number of errors	–0.07	0.59	–0.91	0.37

TMT – Trail Making Test; BMI – Body Mass Index; *p – statistically significant.

Tab. 4. Spearman's ρ correlation coefficients for **HDL and LDL cholesterol levels** and performed tests.

Variable	HDL		LDL	
	Spearman's ρ	*p*-value	Spearman's ρ	*p*-value
TMT, part A – time (sec.)	–0.17	0.22	0.08	0.56
TMT, part B – time (sec.)	–0.05	0.73	0.11	0.41
Stroop Test, RCNb time (sec.)	–0.11	0.41	0.24	0.04*
Stroop Test, RCNb – the number of errors	–0.19	0.14	0.02	0.83
Stroop Test, NCWd – time (sec.)	–0.09	0.49	0.18	0.19
Stroop Test, NCWd – the number of errors	–0.12	0.37	0.17	0.22

TMT – Trail Making Test; HDL - high density lipoproteins cholesterol; LDL - low density lipoproteins cholesterol; *p – statistically significant.

tors for the occurrence of type 2 DM include elderly age and the lack of physical activity. These are the variables which may considerably, either directly or indirectly affect the cognitive functionality of patients (Cosway *et al.* 2001; Fontbonne *et al.* 2001; Vera-Cuesta 2006).

Following the data in Table 3, the higher are BMI values, the higher is the efficacy of co-ordination of visual-psychomotor and visual-spatial and verbal efficacy of working memory and executive functions. These results may be somewhat astonishing, since – as we have already emphasised – overweight and obesity, which may be a problem in patients, treated by multiple insulin injections and in patients with type 2 DM, are risk factors of numerous complications, mainly cardiovascular (Kinalska *et al.* 2007). Moreover, subjects with body weight, appropriate for age and height, demonstrate better metabolic control than patients with overweight and obesity (Otto-Buczkowska *et al.* 2006). However, Elias *et al.* (2003) and Han *et al.* (2009) obtained results, which are close to ours. A positive correlation between obesity and cognitive functioning was observed only among the studied men, while it did not concern the female group of patients. In turn, Cournot *et al.* (2006) showed that the higher was BMI, the lower was the efficacy of aural learning. Gazdzinski *et al.* (2010) demonstrated that elevated BMI was associated with neuronal abnormalities mostly in frontal brain regions, which subserve higher cognitive functions and impulse control. Following Taki *et al.* (2008), in men, the regional grey matter volume of the bilateral medial temporal lobes, anterior lobe of the cerebellum, occipital lobe, frontal lobe, precuneus, and midbrain showed significant negative correlations with BMI, while BMI correlations with those of the bilateral inferior frontal gyri, posterior lobe of the cerebellum, frontal lobes, temporal lobes, thalami, and caudate heads were significant positive.

Cholesterol level in blood of the studied subjects was only slightly associated with the efficacy of cognitive functions (see Table 3). The higher is cholesterol level, the lower is psychomotor rate and efficacy, as well as the efficacy of visual-spatial working memory and executive functions. Following the statistical analysis, HDL cholesterol level is not significantly correlated with the cognitive efficacy of the studied subjects (see Table 4). In turn, increased levels of LDL fraction are significantly associated with decreased efficacy of attention processes. Kwiatkowska *et al.* (2005) obtained similar results in their studies (HDL cholesterol concentration drop and LDL cholesterol concentration rise are accompanied by enhanced disturbances of the cognitive apparatus). Moreover, following some authors, an increased cholesterol level in blood is associated mainly with weaker efficacy of memory processes, attention, verbal fluency and decreased reaction time (Atzmon *et al.* 2002; Exel *et al.* 2002). It should also be kept in mind

that dyslipidaemia may bring about arteriosclerosis, leading in consequence, to numerous vascular diseases. These may, in turn, contribute to deteriorated cognitive functioning among diabetics (neuropsychological deficits belong to the most frequent consequences of disturbed cerebral circulation (Raz 2003; Pasquier 2006).

Summing up, it may be stated that the selected indicators of diabetes control affect, in some way, working memory efficacy of those patients. In the studies by Ohmann *et al.* (2010), 70 teen-age patients with diagnosed type 1 DM were examined, the mean age of the patients – 14 years. However, no correlation was found between the level of diabetes control and the efficacy of cognitive functions. The level of glycated haemoglobin (HbA_{1C}) was in that particular case the measure of disease control. According to Biessels *et al.* (2007) appropriate prophylactic and therapeutic management of the risk factors, associated with the cardiovascular system, and proper control of diabetes mellitus are the necessary conditions to reduce the risk for cognitive deficits.

An accurate control and treatment of diabetes mellitus should be provided to the patients with disturbed cognitive functions, but also to those in whom no such deterioration occurred yet. The applied management is to inhibit and stop the progression of cognitive function disorders, what will allow the affected patients to prolong their self-dependence and social functioning. Ryan *et al.* (2006) and de Wet *et al.* (2007) found out that an improvement in metabolic control can ameliorate working memory dysfunction associated with type 2 diabetes. Poor glycaemic control is associated with impaired performance on composite measures of working memory and that modifiable risk factors for glycaemic control may explain this relationship (Nguyen *et al.* 2010). The described correlations are identifiable already in a group of diabetic children (McNally *et al.* 2010). Studies of cognitive function efficacy could become one of the criteria for diabetes control or they could also be useful in the evaluation and prognosing of independence degree and the quality of life of affected patients.

The number of patients in the study group may be perceived as a sort of limitation for the reported study, since the number of patients in a group may affect the statistical value of methods. Taking into account the above-mentioned doubts, the authors suggest to interpret the presented results with some caution, emphasizing, however the unquestionable fact of the observations in the presented study, while their interpretation requires further support in subsequent research.

CONCLUSIONS

A higher working memory efficacy was demonstrated among patients with type 1 diabetes mellitus vs. the patients with type 2 DM.

The degree of diabetes control was associated with working memory efficacy in the studied patients.

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