Mental Health in Family Medicine 2009;6:99–106

Article

Mental ability performance among adults with type 2 diabetes in primary care

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ABSTRACT

Aim and method The present university-based outpatient clinic, cross-sectional study assessed cognitive performance in a sample of 137 adults, with the primary objective of determining differences in cognitive performance as a function of gender and hypertension status in a type 2 diabetes cohort.

Results Approximately 64% of the sample was 65 years old and younger, and 50 subjects had ≥13 years of education. Global mental ability scores were relatively similar by age grouping, and higher-ordered cognitive functioning and reading literacy were strongly correlated, $r(98) = 0.62$, $P < 0.01$. Approximately 30% of the sample posted global mental ability scores in the slow learner range on tasks measuring attention, immediate memory and verbal reasoning. Males achieved higher cognitive functioning scores compared to females on multiple mental ability tasks. The presence of hypertension was associated with significantly worse cognitive performance compared to those subjects without hypertension, $t = 2.11$, $P = 0.03$. Approximately 57% of the hypertension group was classified as mild cognitive impaired.

Conclusion While approximately half of the general population can be expected to demonstrate an average range of performance on cognitive ability measures, such an expectation could be inappropriately generalised to persons diagnosed with type 2 diabetes, even among those who were high school educated.

Keywords: cognitive functioning, gender, hypertension, primary care, type 2 diabetes

Introduction

Assessment of problems in mental functions, including intelligence, judgement, learning, reaction time, speech, thinking and memory is an emerging primary care specialty. Mental functioning represents a multifaceted set of behaviours, different types of information process, learning styles, comprehension, and problem solving in structured and unstructured situations.[1,2] Although problems surrounding adaptive self-care and self-management in diabetes are areas on which research and intervention frequently focus, it is has been less common to study mental functions in non-older adults with diabetes treated in primary care. Empirically documenting the variability of higher-level mental functioning evident in adults with diabetes can inform patient-centred self-management strategies.

A number of behavioural and social challenges have been attributed to the health difficulties of individuals with diabetes. Uncovering the determinants of diabetes self-care underperformance is a national priority that remains elusive.[3] Approximately 50–80% of persons diagnosed with diabetes have knowledge and skill deficits in self-care-related activities, and longer-term glycaemic control, e.g. >6 months, is a national problem in the type 2 diabetes population.[4] The untoward complications associated with poor diabetes control include micro- and macro-vessel disorders, and co-morbid debilitating conditions such as kidney disease, cardiovascular disease, stroke, eye disease, and excessive and preventable hospitalisations and premature mortality.[5–7] The health burden from type 2 diabetes totals an estimated $98 billion in annual costs. This annual cost is primarily associated with complications due to disease management underperformance.

Over the past decade, findings have been mounting that underperformance in activities of daily living, such as academic and work productivity, and appropriate health practices, are linked to individual variation in mental ability functioning.[8] As pointed out by Deary and Batty (2004), cognitive intelligence, as evidenced by psychometric constructs, embodies aspects of human potential and functioning ranging from use of critical thinking skills, learning and information retention, comprehension, generating solutions, and benefiting from past experiences. Others have speculated that greater mental agility enhances individuals' care of their own health.[9,10] Equally, epidemiological studies have shown that cognitive intelligence predicts time to disease, and lower cognitive intelligence is associated with earlier death.[11]

Determining the range and variability in mental ability and performance is an essential element of clinical inference and patient regimen planning. For primary care clinicians working with persons diagnosed with type 2 diabetes, there is growing concern that diabetes is associated with mental ability changes that could affect behavioural self-regulation and self-management, including self-monitoring of daily lifestyle habits, and interfere with optimal control. Primary care providers are starting to refer diabetic patients for neuropsychological evaluation, to determine what relative contribution higher-order mental functions may play in the chronic disease management of diabetes, particularly for non-older adults.

The primary purpose of this study was to determine differences in mental ability performance as a function of sex and hypertension status in a type 2 diabetes cohort. A major assumption was that this information will provide essential findings that will inform the development of both tailored educational self-management, and programmes focusing on adherence to medical regimen. That is, if average mental ability performance is found among the non-elderly type 2 diabetes population, then it is possible to speculate that self-care underperformance is associated with factors beyond cognitive thinking skills. Because a large number of persons diagnosed with type 2 diabetes are at risk for hypertension, an objective of this study was to assess the associations between diabetes, hypertension, and mental ability performance in this sample of non-demented, non-depressed persons all diagnosed with type 2 diabetes. Additional objectives of this descriptive study were to measure and describe the correlation between reading literacy and mental ability performance, and determine differences in mental ability performance by sex.

Methods

Participants

This cross-sectional study is based upon review of a clinic database, from which data extraction was restricted only to cases having a formal medical diagnosis for type 2 diabetes (n = 137). Persons with known dementia and/or psychiatric disturbance (e.g. depression) at the time of the neurocognitive evaluation were excluded from these analyses. Those in the sample had a mean age of 60 years (standard deviation (SD) = 13.8 years), were 50.7% male (e.g. n = 70), and high school educated (mean number of years of education 12.4; SD 3.2). There were 94 subjects (71.2%) with hypertension, 42 males (46.2%) and 49 females (53.8%) had hypertension. For the entire chart-reviewed sample, the ethnic composition included 11 non-Caucasian persons (e.g. 10 persons self-identified African-American), and more than half of the sample reported being married. Data on hypertension status were missing for five subjects. This clinic data study was approved by the institutional review board.

Procedures and measures

Neurocognitive tests are designed to offer good sensitivity to below-normal functioning. The psychometrically measured reading literacy was indexed using the Reading Recognition subtest from the Wide Range Assessment Test-3 (WRAT-3).[12] The WRAT-3 reading subtest is relatively resistant to the effect of age and some types of organic brain disease, and correlates more closely with premorbid intelligence quotient (IQ) than demographic variables.[13,14]

Determining the presence of cognitive decline is an essential element of clinical inference in medical neuropsychology. Word reading tests are used to estimate premorbid intelligence because word reading correlates highly with IQ in healthy adults and is relatively resistant to decline in patients with various brain disorders.[15] Thus, reading literacy represents a baseline from which cognitive changes can be judged. The difference between reading literacy and higher-order cognitive abilities scores is used as an estimate of cognitive change.[16] The reading literacy score was corrected for by age and education, prior to analysis.

Cognitive reasoning skills were measured using the Wechsler Adult Intelligence Scales – 3rd Edition (WAIS-III),[17] which is appropriate for adults aged 16–89 years. This measure is sensitive to alterations in brain functioning and is designed to measure verbal reasoning abilities and visual understanding, with scores being age corrected. Based on population averages, the average score is, by definition, 100, and scores above 100 indicate a higher than average cognitive performance level. Approximately half of the general population has scores in the average range of performance.

Four cognitive subtests from the WAIS-III were used, including the Information, Similarity, Arithmetic, and Digit Span subtests that are considered to be aspects of verbal intelligence. Briefly described, the Information subtest has approximately 29 questions measuring aspects of general knowledge ranging from school-based learning to history, culture, etc. The Similarity subtest measures concept formation. Subjects are asked to say how two seemingly dissimilar items might in fact be similar. The Arithmetic subtest is a combination of 14 mental arithmetic word problems measuring distractibility as well as numerical reasoning. The Digit Span subtest requires the subject to repeat sets of digits initially forwards and then backwards. This cognitive task measures concentration and attention, working memory, immediate auditory recall, etc. WAIS-III subtest scaled scores have a mean of 10 and a standard deviation of 3, and range from 1 to 19 on each subtest. The objective of each subtest is to measure knowledge on a continuum from a little to a lot. A description of cognitive intelligence scores and their educational meaning is given in Table 1.

Data analysis

Descriptive statistics including proportions and means were used to describe the characteristics of the study sample. Demographic stratification was based on meaningful population estimates determination.[18] Since the difference between verbal cognitive performance and visual–spatial performance is less than 12 points, a common clinical practice is to treat the global performance index as an unbiased estimate of cognitive performance.[19,20] Given that both verbal cognitive performance and visual–spatial performance ability indices are nested within the global performance index score (e.g. interdependence scores), some analyses focused on this global performance measure. Table 1 provides a guide for understanding the differences in cognitive performance.

Next, the mean difference in cognitive performance between subjects with and without hypertension was also examined. Then, the study compared mean differences between male and female gender on measures of mental ability functioning, to determine the nature of the variability in scores (frequency distribution, ranges, etc). Within this process, cognitive performance ability measures were evaluated to determine which means between groups were significantly

Table 1 General population description classifications of intelligence quotients

	Educational description	% of population
WAIS-III IQ scores		
130+	Very superior learner	2.2
120–129	Superior learner	6.7
110–119	High average learner	16.1
90–109	Average learner	50
80–89	Low average learner	16.1
70–79	Borderline or slow learner	6.7
Below 70	Extremely slow or with severe learning disabilities	2.2
WAIS-III subtest scaled scores		
16–19	Very superior learner	–
14–15	Superior learner	–
12–13	High Average learner	–
9–11	Average learner	–
7–8	Low Average learner	–
5–6	Borderline or slow learner	–
Below 5	Extremely slow or with severe learning disabilities	–

different from zero. A numerical measure of association between mental ability and other variables of interest are described. The *t* test for independent means was used to compare the means on cognitive measures, where appropriate. Multiple regression techniques were employed to quantify the relationships between several independent or predictor variables and a dependent variable. Cognitive abilities are shown to be attenuated by educational attainment, gender and age; therefore, these variables were included as covariates in the adjusted models. All significance testing was based on a 0.05 level. All analyses were performed using SPSS version 14.

Results

Cognitive performance range and variability

Demographic and cognitive performance characteristics of the subjects are shown in Table 2. Approximately 64% of the sample was 65 years old and younger. Ninety-seven persons had ≥12 years of education, and among this group, 50 persons had ≥13 years of education. The average reading literacy score for the entire sample was 94.2 (i.e. in the average range of performance). As this study was interested in middle-aged and older adults, age was dichotomised as 18–60 years and ≥61 years; education was dichotomised as <12 grade or ≥12 grade. The Levene's test for equality of variances was non-significant for demographic variables, which suggests that the variance was equal among them. There were no meaningful differences found by age and cognitive performance.

Slightly greater than 47%, 65% and 57% of the entire sample achieved less than average verbal cognitive performance index, visual–spatial performance index and global cognitive performance index, respectively. There was a non-significant, six-point difference between performance indices, which were primarily in the low average range of cognitive performance. Mean cognitive performance scores

Table 2 Patient demographics, cognitive performance and literacy characteristics by gender

	Men		Women		Total	
	Mean (*n*)	SD	Mean (*n*)	SD	Mean (*n*)	SD
Age (years)	58.73 (70)	14.43	61.68 (63)	13.20	60.13 (133)	13.89
Years of education	12.59 (69)	2.80	12.17 (63)	3.64	12.39 (132)	3.22
Residence (%)						
Urban	51.4		58.7			
Rural	48.6		39.7			
Hypertension (%)	46.2 (42)		53.8 (49)		71.1 (91)	
WRAT-3						
Reading literacy	92.60 (58)	16.29	95.94 (54)	15.45	94.21 (112)	15.90
WAIS-3 index scores						
FSIQ	90.52 (52)	15.78	84.49 (51)	17.29	87.53 (103)	16.74
VIQ	93.00 (57)	15.43	87.78 (51)	16.88	90.54 (108)	16.26
PIQ	88.54 (52)	17.39	82.76 (51)	16.88	85.68 (103)	17.30
WAIS-3 subtests scale scores						
Information	9.46 (57)	3.14	8.39 (51)	3.11	8.95 (108)	3.16
Similarity	8.50 (58)	2.96	8.04 (51)	3.70	8.28 (109)	3.30
Arithmetic	8.96 (57)	3.18	7.80 (51)	3.70	8.42 (108)	3.28
Digit Span	8.38 (58)	2.78	7.75 (51)	2.68	8.08 (109)	2.74

n values are shown in parentheses
FSIQ = full scale intelligence quotient; PIQ = performance intelligence quotient (i.e. visual–spatial performance index); VIQ = verbal intelligence quotient (i.e., verbal performance index)
Note: index scores are reported for the three IQ scores. The three IQ scores are standardised in such a way that the scores have a mean of 100 and a standard deviation of 15. Scaled scores are reported for the four WAIS-3 subtests. Subtest scaled scores have a mean of 10 and a standard deviation of three

differed significantly for persons by education (P = 0.001), as shown in Table 3.

Gender and hypertension status in cognitive performance

Cognitive performance was analysed for the entire sample, as well as between genders. Approximately 51.4% of subjects (n = 55) scored at or below low average cognitive functioning. As shown in Table 2, males achieved higher scores compared to women on all cognitive performance measures. Women had much worse performance on the Arithmetic and Digit Span subtests.

Hypertension status did not differ by gender, χ^2 (1, n = 128) = 3.68, $P > 0.05$. Fourteen cases of hypertension were identified in the lowest 20% of global cognitive functioning scores, compared to the eight cases detected for persons with global cognitive functioning scores in the top 20% of the sample. Table 3 shows the range of cognitive ability

Table 3 Cognitive ability standard scores and deviations stratified by education, gender and age

Variable	Cognitive ability score		
	FSIQ	PIQ	VIQ
Education			
>High school (*n* = 39)	94.8 ± 15.4	91.3 ± 17.4	97.9 ± 14.3
High school graduate (*n* = 43)	87.7 ± 14.1	86.47 ± 14.9	90.2 ± 14.4
<High school (*n* = 25)	5.5 ± 15.0	75.2 ± 15.5	79.1 ± 13.9
Gender			
Male (*n* = 52)	90.5 ± 15.7	88.5 ± 17.3	93.0 ± 15.4
Female (*n* = 51)	84.4 ± 17.2	82.7 ± 16.8	87.7 ± 16.8
Age (years)			
18–40 (*n* = 8)	88.0 ± 10.5	89.7 ± 8.7	88.0 ± 15.5
41–63 (*n* = 61)	88.2 ± 17.5	87.1 ± 18.3	90.6 ± 16.4
≥64 (*n* = 38)	86.1 ± 15.7	82.3 ± 15.8	90.6 ± 15.3

FSIQ = full scale intelligence quotient; PIQ = performance intelligence quotient (i.e. visual–spatial performance index); VIQ = verbal intelligence quotient (i.e., verbal performance index)

Table 4 The effects of hypertension on subject cognitive ability resources

Multiple cognitive functioning indices	Hypertension plus diabetes		Diabetes without hypertension		*t* test	*P* value (two-tailed)
	Mean (SD)	*n*	Mean (SD)	*n*		
Global performance index	85.11 (16.05)	70	91.46 (16.64)	35	2.11	0.03
Verbal performance index	89.32 (15.97)	75	93.66 (15.53)	35	1.33	0.18
Visual–spatial performance index	82.35 (16.39)	70	91.46 (17.13)	35	2.64	0.009
Verbal subtests						
Information	8.65 (3.01)	75	9.77 (3.19)	35	1.78	0.07
Similarity	8.03 (3.18)	76	8.77 (3.03)	35	1.12	0.26
Arithmetic	8.32 (2.45)	75	8.69 (3.19)	35	0.56	0.57
Digit Span	7.91 (2.45)	76	8.60 (3.22)	35	1.25	0.21

scores stratified by age, education and gender. Table 4 reports the mean differences in performance by hypertension. A full examination of correlation among study variables is reported in Table 5.

Discussion

This study focused on cognitive performance among individuals with type 2 diabetes with and without hypertension. It was observed that the lowest performance was observed for the Digit Span subtest, which is a measure of auditory function, immediate memory and concentration. Approximately 30% of the entire sample earned scores in the slow learner range for the Digit Span and Similarity subtests. An unremarkable difference was observed between subtest scaled scores. The results show that reading literacy was correlated with global cognitive functioning, suggesting that reading ability is a potential surrogate marker for global cognitive functioning. Higher education and reading ability seemed to modestly buffer the effects of hypertension on cognitive performance, which was not the case when hypertension was present in persons with lower education and poor reading ability.

Another objective of this study was to understand how the observed data were affected by gender. Gender differences emerged in this study. At the level of reading fluency, women had relatively higher reading ability scores, but males demonstrated better performance measures of cognitive performance. At least when estimated from reading literacy, the findings suggest that women may have experienced a greater decline in their cognitive performance abilities, particularly when diagnosed with hypertension. Poorer cognitive performance was more likely for persons with hypertension, regardless of gender.

Strengthens and limitations

The findings of this study need to be considered in light of some potential limitations. The link between the diabetes and cognitive performance is probably mediated by additional factors not included in this study's data profile. For instance, lower education is correlated with low health literacy, and low health literacy is shown to increase the risk for patient-directed medication errors, misunderstanding of medical warnings, and poorer healthcare outcomes.[21,22] Similar to other cognitive abilities research in diabetes,[23,24] this study is not immune to the inherent limitations of the research methodology. It should also be acknowledged that the study population was largely Caucasian and data collection from ethnically diverse populations is needed. As patients with diabetes are medically, socially and culturally heterogeneous, data from this study can only speculate at best that the participants were equivalent in diabetes adherence, diabetes duration, diabetes-related

Table 5 Intercorrelations between age, education, reading literacy, mental ability and hypertension

Ability measures	Correlation (*n*)						
	1	2	3	4	5	6	7
1 Age	–	0.02 (127)	0.21^{b} (107)	0.021 (106)	–0.151 (101)	–0.08 (101)	0.152 (128)
2 Education	0.02 (127)	–	0.48^{b} (107)	0.50^{b} (106)	0.37^{b} (101)	0.46^{b} (101)	–0.14 (127)
3 Reading literacy	0.21^{a} (107)	0.48^{b} (107)	–	0.69^{b} (103)	0.44^{b} (98)	0.62^{b} (98)	–0.08 (107)
4 Verbal IQ	0.02 (106)	0.50^{b} (106)	0.69^{b} (103)	–	–0.74^{a} (101)	0.95^{b} (101)–	–0.14 (106)
5 Performance IQ	–0.15 (101)	0.37^{b} (101)	0.44^{b} (98)	0.74^{b} (101)	–	0.92^{b} (101)	–0.25^{a} (101)
6 Full-scale IQ	–0.08 (101)	0.46^{b} (101)	0.62^{b} (98)	0.95^{b} (101)	0.92^{b} (101)	–	–0.21^{a} (101)
7 Hypertension	0.15 (128)	–0.14 (127)	–0.08 (107)	–0.14 (106)	–0.25^{a} (101)	–0.21^{a} (101)	–

$^{a}P < 0.05$, $^{b}P < 0.01$

self-care, blood sugar control, diabetes regimen utilisation (e.g. insulin use) and/or hypertension control. Moreover, sampling error could potentially explain the observed positive findings.

Conclusion and implications for practice

This study should be interpreted in a correlational, not causative, context. The data show that the association of diabetes and hypertension is problematic for cognitive performance, and that the cognitive burden is greater for women. Cognitive performance may present a set of unique challenges that patients and providers will need to factor into care management. Individuals with diabetes may experience cognitive problems that can affect their ability to execute and/or follow through on self-management goal setting.

Type 2 diabetes is a leading health and healthcare outcome disparity, and there is growing evidence that type 2 diabetes increases the likelihood for dementia and adversely affects survival, but these data are largely observed in very elderly individuals with diabetes.[25–27] It is imperative that we study and understand how and to what extent prevention of diabetes-related complications is potentially a determinant of individual differences in cognitive performance abilities. There is a growing thrust in the use of patient-centred behavioural health interventions applied and adapted for leading family medicine and internal medicine practices toward achieving integrative care, but cognitive functioning assessment continues to be under-utilised at a likely cost to medical regimen(s) planning. Developing the research on cognitive functioning in this population will aid clinicians working in this field.

Proficiency in cognitive skills is correlated with education, health and social status in younger and older adulthood.[28] In relation to prior research, few if any associations have been suggested between type 2 diabetes and cognition when examined in middle-aged patients.[29] Why female gender and low educational attainment (e.g. less than 12 years of education) increased the likelihood for worse cognitive performance are questions our data are unable to disentangle. Hypertension appears to have a deleterious effect on brain-behaviour functions, as high blood pressure is associated with reduced cerebral blood flow, reduced metabolism, and increased risk for cerebral vascular disease.[30,31]

Placed in a broader public health framework, the burgeoning evidence does suggest that poorly controlled diabetes places individuals at risk for global brain dysfunction.[32] The lowest performance on specific cognitive ability tasks was in areas that are highly involved in diabetes care management. There is reason to be concerned that for the entire sample, short-term immediate verbal learning was a liability, as was cognitive complexity (i.e. the Similarity subtest scale). As the data indicate, the clinical picture is suggestive of a generalised, as opposed to a localised, reduction in mental ability efficacy. If reading literacy can serve as a subtle proxy for measures of higher-order intellectual abilities, then it needs to reliably mirror change in the mental ability measures. This study sheds light on the potential benefit of cognitive performance assessment in identifying cognitive strengthens and weaknesses for improving patient care planning (e.g. self-management independence), and identifying functional strategies to compensate for cognitive performance weaknesses. By reporting these finding, the research is positioned to examine the role cognitive performance might play in engaging patients in behaviour change, communicating information to patients, and negotiating the goals of care with patients, particularly in persons with diabetes plus other health related complications.

ACKNOWLEDGEMENTS

Thanks to my research assistants, Orita McCorkle, Tierra Rudd and Darin Johnson, who assisted with various aspects of this project.

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CONFLICTS OF INTEREST

None.

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Accepted 21 July 2009