

Diabetes Numeracy and Blood Glucose Control: Association With Type of Diabetes and Source of Care

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The Centers for Disease Control and Prevention estimated in 2011 that 25.8 million Americans have diabetes, and another 79 million are at risk of developing the disease.¹ Furthermore, it was estimated in 2010 and expressed in 2012 dollars that the average lifetime direct medical costs of treating a patient with type 2 diabetes totaled \$85,200, and 53% of those costs were related to treating complications of the disease.² Despite dramatic increases in diabetes prevalence and a rapid expansion of available treatments, many patients with diabetes are unable to reach their disease management goals. Consequently, a burgeoning corpus of literature and policy guidelines have called for increased attention to be paid to ensuring the improvement of patient outcomes in achieving desired disease control and other related disease management goals.

It is well known that both general literacy and health literacy are essential to improved patient health care outcomes; patients must be able to understand their providers' instructions and use them to make appropriate health decisions for disease management.³ In the United States, 90 million adults have basic or below-basic literacy skills, and > 110 million adults have limited numeracy skills.^{4,5} Another estimate states that two out of three adults in the United States cannot perform rudimentary math.³ Although numeracy has been variously defined, a common definition

ties it to the ability of a person to understand and use numbers in daily life.⁴⁻⁶ Diabetes management involves complex recommendations for self-care that include monitoring blood glucose, administering medications, and appropriately modifying dietary intake.⁷ Effective accomplishment of such tasks necessitates the application of numeracy skills. People with diabetes often must employ numeracy skills in daily activities such as interpreting their blood glucose readings, calculating their carbohydrate intake, adjusting their medications, and performing other self-management activities.^{4-6,8}

Before 2008, no direct tool was available to assess numeracy specifically as it relates to diabetes.⁶ Since then, many instruments have been developed to assess diabetes numeracy. Among these is the Diabetes Numeracy Test (DNT). This tool was developed and vali-

dated by Vanderbilt University and has been in use since its release to assess diabetes-related numeracy.⁶ The DNT is available in three versions. The two most commonly used in clinical settings are a short version with five items (DNT-5) and a longer one with 15 items (DNT-15), with the total scores ranging from 0 to 5 and 0 to 15, respectively. Total score values at the lower end of the range signify low numeracy, whereas total score values at the higher end of the range represent high numeracy.

A review of the literature shows that numeracy is a significant problem in diabetes self-management.^{3,5,7-9} Approximately 25% of patients could not determine what glucose values were within the normal range, 56% could not correctly count the carbohydrates in a pre-packaged snack, and 59% could not calculate an insulin dose based on a blood glucose reading and carbohydrate intake.^{4,9} A recent study⁹ found that low DNT scores were associated with lower levels of perceived self-efficacy, fewer self-management behaviors, and poorer glycemic control. The authors of that study suggested that perhaps the relationship between diabetes-related numeracy and glycemic control is stronger in type 1 diabetes than in type 2 diabetes. One issue that has not been adequately addressed in the extant literature hinges on whether diabetes care from specialists such as diabetologists/endocrinologists is associated with higher

IN BRIEF

Limited diabetes numeracy may be an important factor affecting diabetes care and treatment adherence. This study assessed the relationship between the Diabetes Numeracy Test (DNT-15 score) and patient and treatment variables. Patients who had type 1 diabetes and those who received care from specialty centers had higher levels of numeracy, but this did not translate into improved glucose control.

patient numeracy and improved glycemic control compared to care received from primary care physicians (PCPs).

The overall purpose of this study was to assess diabetes numeracy using the DNT-15 in a sample from a rural population of patients with diabetes. Two specific purposes were 1) to compare the diabetes numeracy and blood glucose control of patients who received care from diabetologists/endocrinologists in a diabetes-focused center to those receiving care from PCPs in primary care facilities and 2) to evaluate the numeracy and blood glucose control of participating patients with type 1 diabetes versus those with type 2 diabetes.

Methods

Data were collected for this cross-sectional study from 1 June 2012 to 31 March 2013. A total minimum sample size of 128 was calculated before the study based on a medium-sized effect (a standardized difference of 0.5 in numeracy and A1C scores) to yield a power of 0.80 for a two-tailed analysis at an alpha of 0.05. Inclusion criteria were: patients must have had type 1 or type 2 diabetes for at least 12 months, be English-speaking, be ≥ 18 years of age, and be able to provide informed consent. Participants were excluded if they did not meet the inclusion criteria or if they were unwilling to participate. Trained research assistants recruited patients from local primary care offices and the diabetes center. Patients were approached at the time of their visit and asked if they would be willing to participate. After informed consent was obtained, research assistants administered the DNT-15.⁶

The DNT-15, which has been validated for the measurement of diabetes numeracy, includes 15 questions, each of which is scored 1 point for a correct answer and 0 for

an incorrect answer, resulting in a minimum total score of 0 and maximum total score of 15. Each question was given equal weight. Survey packets also contained a cover page to collect demographic information, including age, education, estimated number of years with diabetes, facility type where care was received, most recent A1C retrieved from the chart, type of diabetes, and previous completion of formal diabetes education. The research team performed a review of medical records to supplement and verify the demographic information provided by participants. The primary outcomes for this study were the DNT-15 scores of patients who received care from PCPs compared to those of patients who received care from diabetologists/endocrinologists and the DNT-15 scores of patients with type 1 diabetes compared to those of patients with type 2 diabetes.

Summary statistics such as mean, standard deviation, minimum, and maximum were generated for continuous variables, whereas frequencies and percentages were computed for categorical variables. Analysis of covariance (ANCOVA) was used in a general linear modeling framework with the DNT-15 score as the dependent variable. Diabetes type, care facility type (or source of care), sex, and highest level of education attained, as well as the relevant interaction terms, were used as independent factors. Age of participants (evaluated at a mean of 52.9 years) was used as the covariate. This specification enabled adjusting the variation in DNT-15 scores for the effects of each of the independent variables of interest and the appropriate interaction effects. Similar specification was done with A1C scores as the outcome and numeracy scores and the other factors used as independent variables, with age remaining as the covariate

to determine whether numeracy was associated with glucose control.

Other supplementary statistical methods such as the χ^2 test of association or equality of proportions were used in appropriate instances to determine whether relationships between categorical variables or differences in proportions among groups were statistically significant. An independent sample *t* test was used in post-hoc analysis regarding differences between binary categorical variables and the continuous variables (numeracy scores and A1C values). Statistical significance was set at $P < 0.05$. Analyses were completed using SPSS version 21 (IBM, Chicago, Ill.).

Results

Tables 1 and 2 show the general characteristics of the participant sample, as well as the distribution by type of diabetes and care facility. A total sample of 194 patients who met the inclusion criteria completed the DNT-15. Women constituted 61% of the sample (118 of 194), and they represented about 60% of the sample from each type of care facility. Sixty-four percent of the total sample received care at the diabetes center (125 of 194), and 68% of the total sample had type 2 diabetes (132 of 194). Those patients with type 2 diabetes were almost equally split between receiving care in the diabetes center and receiving care from a PCP (49.2% [65 of 132] and 50.8% [67 of 132]), respectively).

The mean age was 53.1 years for the total sample, 50.8 years for the diabetes center, 57.2 years for PCP care, 41.2 years for those with type 1 diabetes, and 58.6 years for those with type 2 diabetes. The average number of years with diabetes (mean duration of diabetes) was 13.8 years in the total sample, 16 years for those receiving treatment from the diabetes center, 9.9 years for those receiving PCP treatment, 19 years for

Table 1. General Characteristics of the Study Participants (n = 194)

| | <i>n</i> | Mean (SD) or % |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------|
| Age* (years) | 193 | 53.08 (15.14) |
| Sex | | |
| Male | 76 | 39.2 |
| Female | 118 | 60.8 |
| Diabetes type | | |
| Type 1 | 62 | 32 |
| Type 2 | 132 | 68 |
| Type of care | | |
| Diabetes center (diabetologist/ endocrinologist) | 125 | 64.4 |
| PCP | 69 | 35.6 |
| Years with diabetes* | 193 | 13.78 (10.70) |
| Highest level of education | | |
| Less than high school | 95 | 49.5 |
| High school | 52 | 27.1 |
| Some college | 27 | 14.1 |
| College of higher | 18 | 9.4 |
| *Total sample size was 194, but deviations from this are the result of missing data for the respective variables. The n = 193 for the variables of age and years with diabetes implies that there was one patient for whom age and years with diabetes was not recorded or data were missing. | | |

those with type 1 diabetes, and 11.3 years for those with type 2 diabetes.

Regarding the highest level of formal education completed, 31% of participants from the diabetes center had some college education, compared to 9% of those receiving PCP care ($P < 0.001$). Similarly, 34% of patients with type 1 diabetes compared to 18% of those with type 2 diabetes had at least some college education ($P = 0.010$).

Problem-solving and knowledge of self-monitoring of blood glucose are key numeracy-related actions required for diabetes management. For this reason, participants were asked if they adjusted medications based on their blood glucose

readings. Nearly two-thirds of the diabetes center patients (63%, or 79 of 125) responded that they make medication adjustments based on glucose readings compared to 28% (19 of 69) of PCP patients ($P < 0.001$). Diabetes center patients were more likely to use injectable medications (66.4% [83 of 125] compared to 41% [28 of 69] of PCP patients, $P < 0.001$). Similarly, 36% of diabetes center patients (45 of 125) reported using an insulin pump compared to 3% (2 of 69) of PCP patients ($P < 0.001$). When asked whether they calculate insulin doses based on carbohydrates, 44% of the diabetes center patients (55 of 125) compared to 7% of the PCP patients (5 of 69)

answered affirmatively ($P < 0.001$). Conversely, 80% (55 of 69) of PCP patients reported taking oral medications for their diabetes compared to 43% (54 of 125) of diabetes center patients ($P < 0.001$).

The successful completion of diabetes education can potentially improve diabetes numeracy. More than three-fourths (79.8%) of diabetes center patients reported that they had completed diabetes education at least once, whereas only 37.7% of the PCP patients reported having done so. About 54% of patients with type 2 diabetes reported ever having had diabetes education compared to 88.5% of those with type 1 diabetes. There was a statistically significant difference in numeracy scores between patients who reported having had diabetes education and those who did not ($P < 0.001$).

The overall ANCOVA model was statistically significant ($P < 0.001$). However, no interaction effects were statistically significant. In other words, the main effects of type of care and type of diabetes could be interpreted separately without regard to each of their levels. A statistically significant difference was found in the adjusted DNT-15 scores between participants who received care from the diabetes center and those who received care from PCP clinics ($P = 0.002$), controlling for sex, type of diabetes, and highest level of education completed, as well as co-variation of age. Similarly, there was a statistically significant difference in DNT-15 scores based on the highest level of education completed ($P = 0.004$), adjusting for the effects of the other variables. However, diabetes type ($P = 0.842$) and sex ($P = 0.062$) were not statistically significant with respect to adjusted DNT-15 scores. It may be worth noting that there was a statistically significant difference in DNT-15 scores by diabetes

Table 2. Distribution of Participant Characteristics by Type of Diabetes and Type of Care

| | Diabetes Type | | Type of Care | |
|-------------------------------------------|---------------|---------------|-----------------|---------------|
| | Type 1 | Type 2 | Diabetes Center | PCP |
| Age [mean (SD)] | 41.16 (15.76) | 58.58 (11.20) | 50.77 (16.48) | 57.22 (11.36) |
| Sex [n (%)] | | | | |
| Female | 39 (62.9) | 79 (59.8) | 76 (60.8) | 42 (60.9) |
| Male | 23 (37.1) | 53 (40.2) | 49 (39.2) | 27 (39.1) |
| Years with diabetes [mean (SD)] | 18.98 (13.22) | 11.32 (8.38) | 15.97 (11.46) | 9.86 (8.11) |
| Type of diabetes [n (%)] | | | | |
| Type 1 | NA | NA | 60 (96.8) | 2 (3.2) |
| Type 2 | NA | NA | 65 (49.2) | 67 (50.8) |
| Previous diabetes education [n (%)] | | | | |
| Yes | 54 (88.5) | 71 (53.8) | 99 (79.8) | 26 (37.7) |
| No | 7 (11.5) | 61 (46.2) | 25 (20.2) | 43 (62.3) |
| Highest level of formal education [n (%)] | | | | |
| Below high school | 20 (32.3) | 75 (57.7) | 48 (38.7) | 47 (69.1) |
| High school | 21 (33.9) | 31 (23.8) | 37 (29.8) | 15 (22.1) |
| Some college | 12 (19.4) | 15 (11.5) | 22 (17.7) | 5 (7.4) |
| College or higher | 9 (14.5) | 9 (6.8) | 17 (13.7) | 1 (1.5) |
| DNT-15 score* [mean (SD)] | 12.92 (2.25) | 10.05 (4.04) | 12.56 (2.55) | 8.07 (3.10) |
| Most recent A1C* [mean (SD)] | 8.15 (1.52) | 7.55 (1.53) | 7.85 (1.45) | 7.54 (1.70) |

*Mean scores for DNT-15 and mean A1C values were unadjusted in the sense of the model. They were raw mean values calculated from the sample and so may differ from the adjusted means obtained from the model.

type before adjusting the DNT-15 scores for the effects of type of care, sex, and highest level of education attained.

Table 3 shows the adjusted and unadjusted mean DNT-15 scores and mean A1C values. To determine whether DNT-15 scores predicted A1C values, DNT-15 scores were analyzed together with the previous independent variables, and an overall statistical significance was observed ($P = 0.006$). This multivariate statistical significance emanated from type of care ($P = 0.022$), interaction effect of sex and diabetes type ($P = 0.025$), and interaction effect of type of diabetes and DNT-15 score

($P = 0.033$). The sex-diabetes type interaction effect meant that there was a statistically significant difference in mean A1C values between male patients with type 1 diabetes ($8.45 \pm 1.926\%$) and those with type 2 diabetes ($7.56 \pm 1.556\%$) ($P = 0.042$). The interaction effect of type of diabetes and DNT-15 score suggested a negative correlation between DNT-15 scores and A1C values for patients with type 1 diabetes, adjusting for all other variables ($P = 0.043$).

Discussion

Although diabetes numeracy may be an important predictor of adherence to care management, it did not

appear to predict glucose control in this study. Glucose control is one of the most important goals in diabetes management. Patients who received care from specialists at a diabetes center had higher numeracy levels as indicated by higher total DNT-15 scores, higher levels of education completed, and a greater likelihood to have completed diabetes education than patients who received care from PCPs. However, these factors did not result in improved glucose control as measured by most recent A1C values. This finding was surprising. However, it is possible that the patients seen at specialty centers typically have more advanced disease. In this study, those

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Table 3. Adjusted and Unadjusted Group (Type of Care and Type of Diabetes) Means for DNT-15 Scores and A1C Values

| | DNT-15 Scores [mean (SD)] | | A1C Values [mean (SD)] | |
|-------------------------------|------------------------------|--------------|---------------------------|-------------|
| | Adjusted | Unadjusted | Adjusted | Unadjusted |
| Type of care | | | | |
| Diabetologist/endocrinologist | 12.905 (0.30) | 12.56 (2.55) | 7.886 (0.13) | 7.85 (1.45) |
| PCP | 9.384 (0.64) | 8.07 (3.10) | 7.647 (0.181) | 7.54 (1.70) |
| Type of diabetes | | | | |
| Type 1 | 11.95 (0.55) | 12.92 (2.25) | 8.167 (0.23) | 8.15 (1.52) |
| Type 2 | 11.426 (0.37) | 10.05 (4.04) | 7.632 (0.14) | 7.55 (1.53) |

receiving care from a diabetes center had a significantly longer duration of disease, were more likely to have type 1 than type 2 diabetes, and were much more likely to be taking an injectable therapy or using an insulin pump. Furthermore, based on the 2012 American Diabetes Association and European Association for the Study of Diabetes guidelines for treating hyperglycemia in type 2 diabetes,¹⁰ a less stringent glucose target may be appropriate for patients with more complicated diabetes. Finally, it is possible that patients seen at the diabetes center did not receive optimal care or that those at the PCP clinics received exceptional care.

The group receiving care at a PCP clinic had a lower average DNT-15 score but was made up almost entirely of patients with type 2 diabetes. Participants in this group were also less likely than those at the diabetes center to have more than a high school education. Despite these factors and low numeracy scores, these patients were able to manage their diabetes to a degree of control similar to that of patients at the diabetes center. It is possible that numeracy scores are less important in people who take oral medications rather than injectable medications. Furthermore, as it has become increasingly difficult to get insurance coverage for glucose test

strips, more and more patients are managing their diabetes without monitoring their blood glucose, and this may explain why numeracy is less important.

One surprising result of this study was the finding that higher numeracy scores did not predict better glucose control as defined by most recent A1C values. This may be the result of a number of factors. It is possible that patients with lower A1C values and lower levels of numeracy may be experiencing greater glucose variability with more frequent high and low glucose excursions, resulting in a similar mean to those with more stable glucose levels. It may also be possible that this population has skills other than numeracy that help with glucose control. This is an area for future research.

There are a number of limitations to this study. The patients completed the tests on their own unless they requested help from one of the assistants. However, they were rarely alone in the room and may have sought help from their visit companion. In addition, the study relied on only one A1C reading as a measure of glucose control. This value may or may not reflect the patient's long-term level of control and does not capture glucose variability or excursions.

Next steps for future research should include comparing DNT-15 scores before and after patients receive a specific, targeted educational intervention that addresses numeracy domains. Carrying this out experimentally can serve to measure numeracy deficiencies, assess glucose control over a longer study period, and determine whether improved numeracy correlates with desired outcomes such as optimal A1C values and high levels of reported self-efficacy regarding diabetes management.

Implications and Relevance for Diabetes Care Providers and Educators

Limited diabetes numeracy is a common problem for people with diabetes and may go unnoticed by providers unless screening tools are used. Although results from this study did not suggest that better glucose control was associated with higher DNT-15 scores, low numeracy may still be a barrier to adequate glucose management for subsequent diabetes control and should be addressed.

It is crucial for providers to be aware of and to know how to use educational tools to improve patient literacy and numeracy. This knowledge may help patients achieve and maintain better glucose control through more effective self-care. It is our belief that patients' understand-

ing of their treatment plan can be directly linked to their adherence to that plan. Increased adherence and shared decision-making are only possible if literacy and numeracy are properly recognized and addressed.

Conclusion

All health care providers who work with patients with diabetes should be aware of the challenges posed by low literacy and numeracy skills, specifically those related to diabetes self-care in general and adherence to individualized treatment plans in particular. That being said, providers should make efforts to screen for limited numeracy and literacy and deliver care that acknowledges patients' individual skill level.

Current diabetes self-management education does address some important numeracy skills, including those related to nutrition and blood glucose monitoring. Education regarding medication-taking and calculating insulin doses often is also included, but this is usually tailored based on whether patients use insulin. This training may be less effective in individuals who have inadequate numeracy skills.

Many of the tasks related to successful diabetes management involve multi-step problem-solving, one of the highest-level and most difficult numeracy skills. When patients struggle with these types of calculations, they may make mistakes in dosing or even abandon treatment plans altogether. If providers take the time to identify patients with low numeracy skills and provide them with more individualized education or specific tools, their adherence to self-care behaviors and glucose control will likely improve. Further

investigation should be performed to compare the differences among available education programs and tools. Finally, numeracy is just one barrier to improved glucose control. Practicing with a questioning mind and identifying and addressing other barriers should be a goal for all diabetes care providers.

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