Correlations Between A1C and Diabetes Knowledge, Diabetes Numeracy, and Food Security in a Vulnerable Type 2 Diabetes Population

Clipper F. Young,[1,2] Kenneth Yun,[1] Edward Kang,[3] Jay H. Shubrook,[1] and Joy A. Dugan[1,3]

ABSTRACT

Type 2 diabetes is over-represented in vulnerable populations. Vulnerable patients managing diabetes are challenged with less-than-optimal processes and outcomes of care; thus, *Healthy People 2020* and the American Diabetes Association have renewed the focus on social determinants of health with regard to the management of chronic diseases such as diabetes. This study explored the correlations between A1C and social and personal factors, including diabetes knowledge, diabetes numeracy, and food security. The Diabetes Numeracy Test-15, the Spoken Knowledge in Low Literacy Diabetes Scale, and the U.S. Department of Agriculture Food Security Questionnaire were administered to a Caucasian study population (n = 96) receiving diabetes care at a federally qualified health center. Although the correlation coefficients generated by the results obtained from the three questionnaires and A1C levels were generally small, a correlation coefficient of 0.46 was found between food security and A1C. An improved understanding of factors that contribute to the successful self-management of diabetes is necessary to improve diabetes outcomes in vulnerable populations.

One in eleven Americans have been diagnosed with type 2 diabetes (1), and less than half of these patients attain recommended A1C targets (2). There are many reasons for this treatment gap, including patient, provider, and systematic factors. Because social determinants of health can greatly affect diabetes management, it is important to assess how issues such as literacy and access to healthy food affect glycemic control (3,4).

Every decade, the U.S. Department of Health and Human Services releases a document titled *Healthy People*, with the goal of improving health in the United States by reducing health disparities and inequalities. *Healthy People 2020* objectives regarding social determinants of health include reducing the proportion of people living in poverty, reducing household food insecurity, and increasing the proportion of patients who receive easy-to-understand information about their health care (5). Furthermore, diabetes has been given its own topic area in *Healthy People 2020* that includes goals for both management and prevention.

Diabetes Numeracy

The American Diabetes Association's *Standards of Medical Care in Diabetes—2017* placed a renewed emphasis on diabetes self-management education (DSME), literacy, and numeracy for optimizing management of diabetes (6). Diabetes numeracy refers to whether a person has the mathematical skills to effectively self-manage diabetes and is an independent predictor of self-management behaviors and outcomes (7). Diabetes numeracy skills are needed for patients with di-

[1]College of Osteopathic Medicine, Touro University California, Vallejo, CA

[2]College of Pharmacy, Touro University California, Vallejo, CA

[3]College of Education and Health Sciences, Touro University California, Vallejo, CA

Corresponding author: Joy A. Dugan, joy.dugan@tu.edu

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abetes to count carbohydrates, read food labels, titrate insulin doses, and administer prescription medications (7). Approximately 110 million adults in the United States have limited numeracy skills (8). Diabetes numeracy can be assessed using the Diabetes Numeracy Test (DNT)-15 (9), and patients' diabetes knowledge can be captured by the Spoken Knowledge in Low Literacy Diabetes (SKILLD) Scale (10).

Although numeracy is positively associated with intermediate outcomes such as self-efficacy and self-care, the relationship between diabetes numeracy and glycemic control is inconclusive (11). In one study, poorer glycemic control was found among African Americans with lower diabetes numeracy scores (12). Zaugg et al. (13) noted that higher diabetes-related numeracy was found among type 2 diabetes patients who received care from specialty diabetes centers managed by an endocrinologist or a diabetologist; however, the higher diabetes numeracy did not translate into improved glucose control measured by A1C values, indicating the possibility that independently low diabetes numeracy is not as closely associated to poor glycemic control as was found in other studies.

Food Insecurity

Food insecurity is defined by the U.S. Department of Agriculture (USDA) as "having limited availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (14). Individuals with food insecurity are more likely to report difficulties affording healthy food options (15). This issue is compounded by the fact that low-income communities have 75% fewer chain supermarkets than middle-income communities (16). Discriminatory pricing of food is a major issue, especially within minority communities, because non-chain supermarkets tend to be more expensive (17,18).

Household food insecurity increases the likelihood of being overweight or obese, increases the prevalence of diabetes by two to three times, and is correlated with higher A1C values (15,19,20). Food insecurity often forces individuals to purchase lower-quality, higher-calorie foods, possibly contributing to weight gain and poor control of type 2 diabetes (21,22). In a study of 711 participants, food-insecure participants' mean A1C was 0.47% higher, in part because of poor diet adherence, poor self-management, and difficulty dealing with emotional distress (15). In the same study, food-insecure individuals were significantly more likely than food-secure individuals to have poor glycemic control, which was defined as A1C >8.5% (42 and 33%, respectively) (15). Furthermore, patients with food insecurity and diabetes are more likely to experience hyper- and hypoglycemic episodes, further complicating the management of diabetes (23).

This study explored the role of food security, diabetes numeracy, and diabetes knowledge in the management of type 2 diabetes in a vulnerable urban population. Through the use of the USDA Food Security Questionnaire (24), DNT-15 (9), and SKILLD Scale (10), this study evaluated the correlations between the results from these survey instruments and individuals' A1C.

Methods

Design and Participants

This cross-sectional study of individuals with type 2 diabetes was conducted in patients with appointments at two primary care federally qualified health centers in Solano County, Calif. Inclusion criteria for patient recruitment were a diagnosis of type 2 diabetes, English-speaking, ≥18 years of age, and able to provide informed consent during the months between March and October 2015. The study was approved by the Touro University California institutional review board and the Solano County Clinical Steering Committee. All participants provided written informed consent before participating in the study.

Data Collection

Patients were approached at the time of their appointment and asked if they were willing to participate in the study. After informed consent was obtained, research assistants administered the USDA Food Security Questionnaire, DNT-15, SKILLD Scale, and a demographic questionnaire. Surveys were either read aloud verbatim by trained research assistants or self-administered by patients. A1C was then obtained from patients' electronic medical charts.

Survey Instruments

The primary outcomes of this study were correlations between A1C and the results from the SKILLD, DNT-15, and USDA Food Security Questionnaire. All three surveys were scored and evaluated as continuous variables by inherent scoring criteria. Table 1 describes the questionnaire scoring.

Statistical Analysis

Statistical analyses were structured into two levels: *1*) descriptive analysis and *2*) measure of linear dependence by determining Pearson product-moment correlation coefficients. Descriptive analysis captured the demographics of the study population in terms of means, SDs, and 95% CIs for basic characteristics (e.g., age, duration of diabetes, A1C, SKILLD Scale score, and DNT-15 score). Numbers (*n*) and percentages were also incorporated to describe variables of the following characteristics: sex, ethnicity, highest level of education, total annual household income, received previous diabetes education, and food security.

Qualitative data on surveys were coded by translating responses to an ordinal quantitative scale. For example, for SKILLD Scale question 1, "What are the signs and symptoms of high blood sugar?," incorrect answers were coded 0 and correct answers were coded 1. Descriptive analysis was conducted on categorical variables to

TABLE 1. Descriptions of SKILLD Scale, DNT-15, and USDA Food Security Questionnaire

SKILLD Scale (10)	• Validated 10-item survey developed to assess diabetes self-management and knowledge in low-literacy patients • Score range: 0–10
DNT-15 (9)	• Validated 15-question assessment developed to assess numerical literacy of patients with diabetes • Questions include interpreting serving sizes and calculating insulin doses • Score range: 0–15
USDA Food Security Questionnaire (24)	• Validated open-source, 6-item questionnaire developed to determine food security in the United States • Score range: 0–6 • Food security categories: high (0–1), low (2–4), very low (5–6) • Lower score associated with greater food security

determine the proportion/frequency of the coded responses (i.e., sex, ethnicity, highest level of education, total annual household income, received previous diabetes education, and food security). Univariate analysis was conducted on continuous variables to determine mean values, SDs, and 95% CIs (e.g., age, duration of diabetes, A1C, SKILLD Scale score, and DNT-15 score).

Pearson product-moment correlation coefficient was the main statistical method used to determine correlations between A1C and each of the survey outcomes (food security, diabetes numeracy, and diabetes knowledge) for the entire study population. Further correlational analyses were performed between A1C and the survey outcomes stratified by ethnicity, sex, and duration of diabetes. We set the aforementioned correlations as primary outcomes. Secondary outcomes were correlations between scores from two surveys, correlations between survey scores and socioeconomic status (SES), and correlations between survey scores and duration of diabetes. All statistical analyses were conducted using Stata 2013 (StataCorp, College Park, Tex).

Results

Socioeconomic, Demographic, and Survey Outcome Characteristics

After excluding individuals with incomplete or missing data, a total of 96 participants were included in statistical analyses. Table 2 depicts participant demographics. The mean age of participants was 56.1 years, and mean duration of type 2 diabetes was 10.6 years. Just over half of the participants (52.1%) were female. More than one-third of the participants (38.5%) were African Americans, and Caucasians comprised 25% of the study population. Close to one-third (31.3%) of the study population had received a high school diploma or equivalent; a little over one-fourth (27.1%) had taken some college courses but did not complete a degree; and 12.5% of the participants did not graduate from high school. The majority of the study population (54.2%) earned <$15,000, although the actual percentage might be greater because 13.5% declined to answer the question about annual household income. Only one person reported having an annual household income >$60,000. Finally, more than half of the participants (57.3%) reported having received previous diabetes education.

Participants' mean A1C was 8.3%, mean SKILLD Scale score was 10.1, and mean DNT-15 score was 6.3. The majority of the participants (54.2%) had low or very low food security,

TABLE 2. Demographics (*n* = 96)

	Mean	SD	95% CI
Age (years)	56.1	10.3	54.0–58.2
Duration of diabetes (years)	10.6	8.5	8.9–12.3
A1C (%)	8.3	2.3	7.9–8.8
SKILLD Scale score	10.1	3.1	9.5–10.7
DNT-15 score	6.3	4.1	5.5–7.1
		n	**Percentage**
Sex			
Male		43	44.8
Female		50	52.1
Transgender or preferred not to answer		3	3.1
Ethnicity			
Caucasian		24	25.0
African American		37	38.5
Other (Asian, Hispanic, mixed)		35	36.5

TABLE CONTINUED ON P. 180 →

TABLE 2. Demographics (*n* = 96), ***continued from p. 179***

	n	Percentage
Highest level of education		
Less than high school diploma	12	12.5
High school diploma/GED	30	31.3
Some courses in college but no degree	26	27.1
Associate's degree	11	11.5
Bachelor's degree	14	14.6
Graduate degree	3	3.1
Total annual household income		
<$15,000	52	54.2
$15,000–30,000	15	15.6
$30,001–$45,000	10	10.4
$45,001–$60,000	5	5.2
>$60,000	1	1.0
Preferred not to answer	13	13.5
Received previous diabetes education		
Yes	55	57.3
No	41	42.7
USDA Food Security Questionnaire score		
High to marginal food security	44	45.8
Low food security	23	24.0
Very low food security	29	30.2

as determined via the USDA Food Security Questionnaire.

Primary Outcomes

Of the three surveys, results from the USDA Food Insecurity Questionnaire exhibited the strongest correlation (*R*) with A1C, as shown in Table 3. As depicted in Table 4, when food security data were stratified by ethnicity, food security scores and A1C had a correlation of 0.46 in Caucasians. The Other ethnicity group, which included mostly Asians, Hispanics, and individuals of mixed race, exhibited the strongest correlation (*R* = 0.31) between DNT-15 score and A1C. The correlation between SKILLD Scale scores and A1C was strongest in African Americans (*R* = 0.26).

When data from the three surveys were stratified by sex, correlations between survey results and A1C were stronger in men across all three instruments; detailed correlations are shown in Table 5. The strongest correlation (*R* = 0.30) was between SKILLD Scale scores and A1C in men. When stratified by duration of diabetes, results from all three surveys and A1C exhibited stronger correlations in those who had been dealing with diabetes for a longer period of time, as shown in Table 6. Of the three sets of survey results, those from the food insecurity survey correlated the strongest with A1C in those who had had diabetes for a longer duration.

Secondary Outcomes

We also explored correlations between individual results from two survey instruments. The correlation between SKILLD Scale scores and DNT-15 scores exhibited an *R* of 0.47, as shown in Table 7. The correlations between results of the food security survey and results from the other two survey instruments showed negative trends.

The correlations between results from the three surveys and components of SES are summarized in Table 8. Negative correlations were observed between food security results and both education level and total annual household income. Specifically, the correlation was stronger between total annual household income and food security results (*R* = –0.32) than between education level and food security results (*P* = –0.12). Among all the correlations discovered between individual survey scores and components of SES, the strongest correlation (*R* = 0.34) was found between DNT-15 results and education level.

Discussion

Participants in this study were from a racially and ethnically diverse population and had low SES, which was reflected by more than half of the participants (54.2%) reporting an annual household income <$15,000. The majority of these participants

TABLE 3. Correlations Between Individual Survey Scores and A1C (*n* = 96)

	Food Security	DNT-15	SKILLD Scale
R	0.164	0.111	0.0381

TABLE 4. Correlations (*R*) Between Individual Survey Scores and A1C by Ethnicity

	Food Security	DNT-15	SKILLD Scale
Caucasians (*n* = 24)	0.460	–0.187	0.0524
African Americans (*n* = 37)	0.0614	–0.0126	0.261
All other (*n* = 35)	0.132	0.310	–0.191

TABLE 5. Correlations (*R*) Between Individual Survey Scores and A1C by Sex

	Food Security	DNT-15	SKILLD Scale
Male (*n* = 43)	0.219	0.109	0.296
Female (*n* = 50)	0.101	0.106	–0.152

TABLE 6. Correlations (*R*) Between Individual Survey Scores and A1C by Duration of Diabetes

	Food Security	DNT-15	SKILLD Scale
Longer duration (above mean) (*n* = 39)	0.234	0.197	0.140
Shorter duration (below mean) (*n* = 57)	0.104	0.0458	–0.0482

TABLE 7. Correlations Between Scores on Two Individual Surveys (*n* = 96)

	Food Security Versus SKILLD Scale	Food Security Versus DNT-15	SKILLD Scale Versus DNT-15
R	–0.0943	–0.211	0.471

TABLE 8. Correlations (*R*) Between Individual Survey Scores and Socioeconomic Status

	Food Security	DNT-15	SKILLD Scale
Highest level of education (*n* = 96)	–0.117	0.337	0.169
Total annual household income (*n* = 83)*	–0.323	0.227	0.112

**Thirteen individuals chose not to answer the question in regards to total annual household income.*

expressed low levels of food security. Despite these challenges, only food insecurity was related to A1C in this study population. Lower SES can contribute to greater challenges in maintaining health and, in this case, to managing diabetes, thus leading to a higher level of health impairment and lower health-related quality of life (25).

In addition, >70% of the study population did not have a college degree. The participants had lower DNT-15 scores compared to the original DNT-15 study population (mean score 42 vs. 61%) (9), further highlighting the great need for education in this group. Our study population had a lower level of diabetes numeracy, indicating that the participants may face more mathematical challenges with aspects of DSME such as insulin titration and reading food labels.

Previous studies have found that only 6.8% of individuals received formal diabetes education (26). Yet, self-reported participation in formal diabetes education was much higher in this study population (57.3%). This is surprising in that there were no certified diabetes educators in the health system at the time of the study. However, this study did not assess the quality, chronology, or type of diabetes education. There was moderate correlation (*R* = 0.47) between results from the SKILLD Scale and the DNT-15, suggesting that knowledge has a positive relationship to numeracy skills. However, there was poor correlation between A1C and SKILLD Scale scores. This fact demonstrates that success with diabetes self-management and glucose control are multifactorial and that individuals with low levels of diabetes knowledge can in fact successfully control their disease.

Understanding patients' degree of food security is important for providing individualized dietary recommendations. Because more energy-dense foods (e.g., pasta, rice, and cookies) cost much less per calorie than foods typically recommended in DSME (e.g., fruits, vegetables, and lean protein) (27), patients with less food security may not be able to afford foods typically recommended by diabetes health care professionals. In this study population, there was a high degree of food insecurity, with 54.2% having low or very low food security. Caucasian participants (*n* = 24) had the highest correlation between degree of food security and A1C among the three groups stratified by ethnicity. This highlights the importance of making lifestyle (nutrition and physical activity) recommendations that fall within patients' cultural norms and means. Otherwise, these recommendations will be nearly impossible to follow and may actually hinder open communication between providers and patients.

Limitations

There are a number of limitations in this study, including interviewer bias. The SKILLD Scale survey was designed to be read aloud to patients during its administration. A small subset of participants completed the survey on their own without questions and answers read aloud. Patients completed the other questionnaires on their own unless they requested help from one of the research assistants. Patients often had other people in the room and may have received help from them.

This study only included people who were proficient enough in English to complete the informed consent and elements of the study in English. This was a significant barrier for recruiting Hispanic and Asian participants, resulting in selection bias. The results likely would have differed if non-native English speakers were included.

This study did not investigate differences in knowledge and numeracy levels based on medication type. More research is needed to determine whether individuals who are on insulin actually have or gain adequate numeracy skills to self-manage and self-titrate their insulin. Individuals participating in this study who were not on insulin often reported to research assistants that they did not understand why they were being asked questions about insulin titration. In response to such questions, some participants said they could not answer because they were not taking insulin. This led to a number of incomplete surveys.

Although diabetes numeracy was not found to be correlated to glucose control in this study, A1C is only a small snapshot of long-term glucose control. A person with glucose variability (multiple high and low glucose levels) may have an A1C similar to somebody with more stable glucose levels. More research is needed to determine the full impact of numeracy level on patients, and especially on those with newly diagnosed diabetes.

Clinical Implications

Diabetes is a complex disease, and patients are primarily responsible for self-management to attain glucose control. It has been estimated to take 3 hours/day to complete all of the recommended diabetes self-care behaviors for a person with type 2 diabetes (28). Ensuring that the diabetes care team teaches self-care skills that are appropriate to patients' literacy and numeracy levels could lessen the time burden of DSME. Furthermore, low levels of diabetes numeracy may go undetected by the diabetes health care team unless screening tools such as the DNT-15 are used (13). Although glucose control was not correlated with higher DNT-15 scores in this study, low diabetes numeracy may still be a barrier to optimal diabetes management and should be addressed. Future research should compare DNT-15 scores before and after a DSME program in newly diagnosed individuals to determine whether numeracy correlates with more optimal A1C earlier in disease management.

Conclusion

The most vulnerable patients with diabetes are also most likely to face issues with food insecurity, diabetes knowledge, and diabetes numeracy. Members of the diabetes care team should consider assessing diabetes numeracy and food security to provide patients with the most individualized DSME options possible. Multiple social determinants of health within a patient's environment, including access to nutritious foods, safe walking spaces, transportation, and social support, can affect diabetes control. More interdisciplinary interventions are needed to improve the diabetes care process and outcomes of vulnerable patients. Recognizing individual patients' level of literacy, numeracy, education, and food security could increase adherence and shared decision-making in diabetes care.

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Duality of Interest

No potential conflicts of interest relevant to this article were reported.

Author Contributions

All authors participated in researching data, discussion, and writing, reviewing, and editing the manuscript. J.A.D. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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