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Glycemic control and self-rated health among ethnically diverse adolescents with type 1 diabetes

Naomi S. Kane^{1,2}, Claire J. Hoogendoorn², Persis V. Commissariat^{3,4}, Talia E. Schulder², Jeffrey S. Gonzalez^{2,5,6,7}

¹War Related Illness and Injury Study Center (WRIISC), VA New Jersey Health Care System, East Orange, New Jersey

²Ferkauf Graduate School of Psychology, Yeshiva University, Bronx, New York

³Pediatric, Adolescent, and Young Adult Section, Section on Clinical, Behavioral, and Outcomes Research, Joslin Diabetes Center, Boston, Massachusetts

⁴Department of Psychiatry, Harvard Medical School, Boston, Massachusetts

⁵Department of Medicine (Endocrinology) and Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, New York

⁶The Fleischer Institute for Diabetes and Metabolism, Albert Einstein College of Medicine, Bronx, New York

⁷The New York Regional Center for Diabetes Translation Research (NY-CDTR), Albert Einstein College of Medicine, Bronx, New York

Abstract

Objective: Patient-reported outcomes have received increased attention as treatment outcomes and indicators of wellbeing. A1c has been criticized as lacking patient-centered relevance because individuals are often unaware of their A1c, and studies also often fail to show a benefit of intensive control on quality of life. The goal of the present study was to examine self-rated health (SRH) in relation to diabetes self-care behaviors, socioeconomic factors, treatment regimen characteristics, and glycemic control among predominately Hispanic and African American adolescents with type 1 diabetes (T1D).

Methods: Adolescents with T1D (N = 84) were recruited for a cross-sectional study evaluating psychosocial factors and identity development. SRH, self-care behaviors, treatment regimen, and demographic variables were collected through self-report while glycemic control (A1c) was determined through chart review.

Correspondence: Naomi S. Kane, War Related Illness and Injury Study Center (WRIISC), VA New Jersey Health Care System, 385 Tremont Ave (129A), East Orange, NJ 07018. naomi.kane@va.gov.

AUTHOR CONTRIBUTIONS

N.K. wrote the paper and performed the analyses, C.H. provided editorial support and wrote sections of the introduction and discussion, P.C. designed the research study and collected data, T.S. contributed to the literature search, and J.G. provided editorial support and advised authors on the conceptual framework, methods and analyses for this study.

CONFLICT OF INTEREST

None declared.

Results: Participants were predominantly racial and ethnic minorities (48% Hispanic, 27% African American; 52% female, M age 15.9, M diabetes duration 6.8, M A1c 10% [86 mmol/mol]). Significant bivariate relationships emerged between SRH and sex, A1c, self-care behavior, and insulin delivery method. Covariate-adjusted regression models showed only A1c was significantly and independently related to SRH. Mediation analyses illustrated a significant indirect effect for A1c between self-care and SRH.

Conclusion: These findings suggest glycemic control is associated with self-ratings of health among ethnically diverse adolescents with T1D. SRH appears to be an appropriate patient-reported outcome that is sensitive to glycemic control in this population.

Keywords

adolescents; glycemic control; self-rated health; type 1 diabetes mellitus

1 | INTRODUCTION

Self-rated health (SRH), consisting of a simple subjective rating of whether one's health is poor, fair, good or excellent, is a well-established predictor of morbidity and mortality among both adults¹ and adolescents.^{2,3} While A1c is often considered to be an indicator of disease progression, roughly a quarter of young adults are often unaware of their A1c value⁴ and about 90% of adolescents are unaware of their target range.^{5,6} Further, A1c improvement has been criticized as lacking proximity to patient-centered outcomes.⁷ SRH may be an appropriate patient-reported outcome that captures perceived changes in health that may precede important health outcomes. While associations between SRH and health outcomes, such as mortality, have received research attention,⁸ factors influencing SRH are less well understood, especially in the context of type 1 diabetes (T1D). A better understanding of the factors that are associated with, and potentially contribute to, one's assessment of health would support SRH as a meaningful patient-reported outcome in T1D.

Data collected from nationally representative surveys among adults show relationships among SRH, socio-demographic variables, physiological sensations, worse health outcomes, and increased risk of mortality.^{9–11} Among adults with diabetes, lower SRH is associated with increased risk of mortality¹² even after controlling for disease indicators such as hypertension and insulin treatment.¹³ Appraisal of one's SRH appears to encompass an overall sense of functioning including social, environmental, behavioral and psychological factors among adults,¹⁰ as well as adolescents.¹⁴ Adolescents of lower socioeconomic status, including those with lower household income¹⁴ or lower perceptions of family wealth,¹⁵ report poorer SRH. Data from a large sample of adolescents in the T1D Exchange Registry showed that lower SRH was associated with female sex, insulin injections rather than insulin pump, and poor glycemic control.¹⁶ Additionally, among children and adolescents, lower SRH is associated with increased severity of diabetes-related physical symptoms including excessive urination, abnormal thirst, fatigue, weight loss, and visual impairments, along with increased frequency of hospitalizations and diabetes-related complications.¹⁷ Similarly, among adolescents with asthma, lower SRH is associated with worse disease severity including wheezing episodes and night coughing.¹⁸ Overall, there is a paucity of studies examining demographic correlates of SRH or SRH as a predictor of outcomes among

adolescents with chronic illnesses. SRH could be a particularly important patient-reported outcome in adolescents with T1D, where subjective evaluations of health may compete with more abstract and often poorly understood^{4–6} blood glucose data in guiding self-care behaviors.¹⁹

Adolescence is a particularly challenging period to achieve and maintain adequate control of T1D due to insulin resistance during puberty, social demands, identity issues, and other psychosocial stressors.^{20,21} Control may also deteriorate during adolescence because other aspects of life and functioning become more important and compete with diabetes for adolescents' attention.²² Race and socioeconomic status also play a role in management of T1D in adolescence. Although T1D is most common among non-Hispanic white children and adolescents, with an incidence rate of 23.6 per 100 000, as compared to incidence rates of 15.7 and 15.0 per 100 000 Among African-Americans and Hispanics, respectively,²³ African American and Hispanic children and adolescents often have worse control of T1D, as compared to their white peers.²⁴ These differences are likely explained in part by higher levels of socioeconomic disadvantage among ethnic minorities.

For example, insulin pump therapy, and its ability to increase glycemic control in the long-term, may improve quality of life (QOL) for adolescents.^{25,26} However, the pump is not accessible to all that may benefit. Adolescents who have private insurance, household incomes >\$100 000, and are non-Hispanic white are more likely to initiate subcutaneous insulin pump therapy.²⁷ Individuals with a parent with a college degree are also more likely to obtain an insulin pump and to regularly monitor their blood glucose levels.²⁸ Many insulin pumps cost at least \$5000 and even with health insurance, these costs can involve large out-of-pocket expenses.²⁹ Further, access to care, the cost of insulin, and insurance are significant barriers to uptake and maintenance of diabetes devices and injections.³⁰

Few previous studies have addressed the intersection of adolescence, T1D, socioeconomic status, and SRH in a racially, ethnically, and socioeconomically diverse sample. This study aims to investigate the correlates of SRH, with particular attention to the method of insulin administration, among a predominately socioeconomically disadvantaged African American and Hispanic sample of adolescents with T1D. We also investigated sex as a moderator of the relationship between SRH and health outcomes based on prior evidence of sex differences relevant to SRH.^{14,15,17} We expected that a less demanding treatment regimen, better self-care, and better glycemic control would be associated with better SRH.

2 | METHOD

2.1 | Participants, setting, and recruitment

Adolescents (ages 13–21) with T1D were recruited from a pediatric endocrinology clinic at an urban academic medical center in the Bronx, New York. Participants had to read and write in English to be eligible. Adolescents with a formal psychiatric diagnosis, terminal illness, or intellectual disability were excluded. Potential participants were identified by clinic staff and approached while waiting for their appointment. This one-time study visit included a brief, 5 to 22 minute (M = 6.4, SD = 3.9), qualitative interview about personal

and social identity with results reported elsewhere,³¹ as well as a battery of validated self-report measures of self-care, self-esteem, peer relationships, and QOL.

A total of 90 participants were approached to participate, with 85 providing consent. One participant was dropped from the analyses due to missing data. Adolescents under 18 provided verbal assent while parents provided written consent. The Institutional Review Board at the Albert Einstein College of Medicine approved this study.

2.2 | Measures

2.2.1 | Self-care behavior—Frequency of diabetes specific self-care behavior was assessed with the Self-Care Inventory-Revised (SCI-R).³² The SCI-R is a 15-item questionnaire evaluating how often diabetes self-care behaviors were carried out over the past one to 2 months. This includes a variety of self-care behaviors comprising adherence to medication, diet, exercise, attendance at doctor's appointments, blood glucose checking, response to low and high blood glucose numbers, and activities specific including adjusting insulin administration level and monitoring ketone levels. Self-care scores were standardized in regression analyses. Internal reliability of the SCI-R was good with $\alpha = .85$.

2.2.2 | Indicators of socioeconomic status and demographics—Household size, parent level of education, parent born outside US, race and ethnicity were collected as indicators of socioeconomic status.

2.2.3 | Self-rated health—SRH was assessed using one-item taken from the Diabetes Quality of Life Youth (DQOLY) survey.³³ Participants were asked, "Compared with others your age, would you say your health is..." with four response options. Consistent with standard practice in this field of research and because of low cell count, SRH was collapsed into two categories (poor/fair and good/excellent).

2.2.4 | Glycemic control—Most recent A1c was collected by review of the electronic medical record.

2.2.5 | Insulin regimen—Participants reported whether they administered insulin through multiple daily injections or a subcutaneous insulin pump.

2.3 | Statistical analyses

Statistical analyses were conducted with SPSS.³⁴ Significance was considered at $P < .05$ unless otherwise indicated. Descriptive statistics, Spearman's rank order coefficients, phi-coefficients, and chi-square evaluated bivariate relationships between study variables and SRH. The use of a dichotomous outcome model of SRH (poor/fair vs good/excellent) is supported by multiple statistic models including logistic regression.^{16,35} Pearson correlation coefficient and t-tests were used between continuous variables. Logistic regression was used to examine the unique effects of socioeconomic indicators and self-care behavior alongside SRH. To reduce bias, one outlier for each A1c and self-care when stratified by collapsed SRH categories was transformed using the Winsorizing method, substituting outliers with the highest value that is not an outlier.³⁶ We followed recommended procedures to evaluate

simple statistical mediation using PROCESS macro for SPSS.³⁷ Bootstrapping estimates were based on 5000 draws with replacement from the current sample.

3 | RESULTS

3.1 | Demographic considerations

Almost half of the 84 participants were Hispanic and over a quarter of the sample were African American (Table 1). The majority of participants (58.3%) had a parent born outside of the United States. Approximately 44% used multiple daily injections of insulin and 56% used an insulin pump. Slightly more than half of participants were female and 89.7% of participants had blood glucose levels greater than 7.5% (58 mmol/mol), which is indicative of suboptimal glucose control among adolescents.³⁸ The average SRH score was 1.58 (SD = 0.70), indicating between “fair” and “good” health (Figure 1).

3.2 | Bivariate associations

Significant correlations were found between better SRH and lower A1c ($\rho = -.47$, $P < .001$), insulin pump therapy ($\phi = .32$, $P = .003$), male sex ($\phi = .27$, $P = .01$), BMI ($\rho = -.24$, $P = .03$), and better self-reported diabetes self-care ($\rho = .30$, $P = .006$). Figure 2 illustrates these significant relationships. Among females, 52.3% used injectable insulin, and 47.7% used an insulin pump, compared with 35% and 65% of males, respectively. SRH was not significantly associated with age ($P = .68$), race ($P = .42$), or duration of illness ($P = .91$). Additionally, SRH was not associated with various indicators of socioeconomic status including mother or father level of education ($P = .74$ and $P = .92$, respectively), or household size ($P = .84$).

Insulin pump therapy was associated with lower A1c ($P < .05$), but did not show a significant association with sex ($P = .11$). Insulin pump therapy did not show a relationship with age, race, or BMI.

Better self-reported diabetes self-care was associated with better glycemic control ($r = -.35$, $P = .001$) and was not associated with other socioeconomic indicators. Indicators of SES (race, household size, parent education) did not show associations with other study variables; thus, these variables were excluded from subsequent analyses.

3.3 | Logistic regression

For every one unit increase in A1c, there was an almost twofold decreased likelihood in reporting good or excellent SRH (OR = 0.57, 95% CI: 0.43–.75, $P < .001$). Males had about a threefold increase in odds of reporting good or excellent SRH (OR = 3.07, 95% CI: 1.25–7.57, $P = .015$), as compared to females. Those on an insulin pump were about four times as likely to report good or excellent SRH (OR = 3.87, 95% CI: 1.56–9.64, $P = .004$), as compared to adolescents on multiple daily insulin injections. Each SD increase in self-care was associated with a twofold increased likelihood of reporting good or excellent SRH (OR = 1.94, 95% CI: 1.19–3.15, $P = .008$). As shown in Table 2, when all predictors (A1c, sex, insulin injection method, self-care) were entered into the same model, only A1c retained independent significance (OR = .60, 95% CI: .44–.82, $P = .002$). Additional analyses, not

shown, assessed whether sex influenced the strength of relationship between each of these independent variables (A1c, insulin injection method, self-care) and SRH; however, sex was not a significant moderator of these relationships (all p s > .06).

3.4 | Mediation analysis

Illustrated in Figure 3, three separate simple mediation path models using Hayes' conditional PROCESS analysis evaluated the indirect effects of type of insulin administration, self-care behavior, and sex upon SRH, mediated through A1c. A1c partially mediated the relationship between insulin pump and high SRH (indirect effect: .57; 95% CI: .08, 1.36). There was a significant indirect path between self-care and SRH via A1c. There was no evidence that self-care behavior had a meaningful relationship with SRH after accounting for this indirect effect ($c' = .36$, $P = .18$), suggesting substantial mediation. Sex was not significantly related to A1c and there was evidence of a direct path between male sex and SRH ($c' = -1.09$, $P = .04$) in the presence of this insignificant indirect relationship between A1c and sex.

4 | DISCUSSION

Overall, results suggest that sex, method of insulin administration, and adherence to self-care are associated with self-ratings of health, with glycemic control accounting for a substantial portion of these effects, among ethnically diverse adolescents with T1D. These findings add to the growing literature that highlight the importance of capturing patient-reported outcomes as part of diabetes care. SRH is a valid predictor of future health status^{1,39} and contributes to assessments of QOL,³³ further highlighting its importance as a patient-reported outcome. The majority of past research examining SRH and chronic disease outcomes has focused on adults.⁴⁰ This study seeks to fill this demographic gap¹⁶ and shed light on the experience of ethnically diverse Hispanic and African American adolescents with T1D. A1c improvement has been criticized as lacking meaning to patients but our results suggest that A1c is significantly associated with subjective overall ratings of health status among adolescents with T1D. Whether treatment and other interventions can affect SRH through improvements in A1c cannot be addressed by our design but should be studied in future research.

Those who endorsed better SRH demonstrated distinct differences compared to peers who endorsed lower SRH, with these differences explained by differences in glycemic control. Specifically, results indicate that individuals who reported lower SRH were female, used multiple daily insulin injections, reported poorer self-care, and higher blood glucose levels, which is consistent with a larger adolescent cohort study.¹⁶ Contrary to our hypotheses and previous literature,^{16,41} socioeconomic status including parent level of education, household size, and race, did not significantly account for variance in SRH. However, our sample differed from previous literature in that the majority of youth in this study were Hispanic or African American. The overall lower socioeconomic status of the population from which the sample was drawn may have limited our ability to assess these relationships. Future research should continue to examine the relationship between race, ethnicity, SES, and SRH among adolescents with T1D.

Lower A1c levels showed a robust association with better SRH, and this relationship was independent of age, sex, self-care, or method of insulin administration. This logistic regression model accounted for between 31.6% and 42.4% of the variance in SRH. While using an insulin pump rather than daily injections was associated with a fourfold increase in good or excellent SRH, this association was no longer significant when A1c entered into the model. The same was observed for self-care, with better self-care showing a significant association with higher SRH until A1c was included in the model. While previous large epidemiological studies have shown associations between A1c and SRH among adults and adolescents with diabetes,^{16,42} none have examined A1c after adjustment of adherence to diabetes self-care. The present study replicates this association in a diverse sample of adolescents and provides evidence that suggests this association is independent of other important influences on A1c. The present results suggest that of the variables examined, A1c is the most closely related to SRH.

Mediation analyses further support A1c as an independent pathway to SRH; that is, the use of the subcutaneous insulin pump and better self-care were associated with better SRH through improved glycemic control. Should these relationships prove causal, they suggest that adolescents may use their knowledge of A1c to evaluate their health. However, previous research suggests many adolescents are unaware of their A1c⁴ or goal^{5,6} and it is possible that unmeasured physical symptoms resulting from hypo- or hyperglycemia are influencing the relationship between A1c and SRH as physical symptoms are correlated with SRH.^{17,43}

Our findings contribute to the growing tension in the literature^{7,44} between focusing treatment on a proxy for health outcomes like A1c vs focusing treatment on improving patient-important outcomes such as perceived health and health-related QOL (for a review see⁴⁵). Previous findings that show a lack of a relationship between intensive treatment and improved QOL^{46,47} suggest that intensive treatment and/or improved glycemic control does not necessarily translate into improved perceptions of wellbeing. The importance of distinguishing health status as a proxy measure for QOL has been discussed⁴⁸ and our results should be interpreted through the lens of improving perceived health status, not QOL. Our findings are in line with a growing interest to systematically capture patient reported outcomes as central measures in diabetes research, as such assessments can provide valuable information about the effects and burdens of treatment (eg, pain severity)⁴⁴ and incorporate the American Diabetes Association's recommendations for a patient-tailored approach to establishing goals for glycemic control.⁴⁹ Inclusion of patient-reported outcomes, such as SRH, could contribute to better patient-centered psychosocial care.

Additional cross-sectional as well as longitudinal studies are needed to assess socio-demographic and illness-related correlates of SRH among adolescents with diabetes. Given that glycemic control tends to drastically decline during this developmental period,^{24,50} adolescent perceptions of their health may be an important area to focus on in determining barriers to self-care and improving health perceptions. Longitudinal research indicates that lower SRH in adolescence is associated with higher biomarkers of allostatic burden into adulthood.⁵¹ Further research might investigate whether improving access to the insulin pump would result in better glycemic control and SRH in this population. It is also possible that those who are educated on technology use and prescribed insulin pumps already possess

more favorable traits including responsibility, enthusiasm, understanding, and better self-care.⁵²

There are several limitations to the current study. First, the use of cross-sectional analyses cannot clarify the direction or causality in these relationships. For example, lower reported SRH among those injecting insulin may be the result of poorer overall glucose control, compounded by perceived difficulties with managing intensive insulin therapy in daily life. Those who are chosen to receive an insulin pump may possess more favorable traits,⁵² which may limit the inferences made here. This sample may not generalize to other populations, particularly less ethnically diverse or non-urban groups. And finally, the unique racial and ethnic composition of this sample may affect generalizability to the general population with T1D, which is primarily non-Hispanic white.⁵⁰

Overall, results of this study suggest that glycemic control, method of insulin administration and adherence to self-care were closely associated with subjective self-ratings of overall health in our sample of adolescents with T1D. This has several implications for practice, including identifying a simple assessment tool that may be useful in identifying patients at risk of worse self-care behavior and glycemic control. Our results indicate that relationships between health-behaviors and SRH can be substantially explained by associated improvements in glycemic control. Due to the cross-sectional nature of the current analyses, directional and causal inferences cannot be ascertained from these data. Future research should aim to understand the factors that influence perceptions of health, and patient-reported outcomes, in comparison with glycemic control and other biological disease markers. If the insulin pump is causally related to improved QOL⁵³ and perceived health functioning, healthcare systems should increase efforts to advocate for better access to the insulin pump for adolescents with T1D, particularly for adolescent females. Use of longitudinal methods to measure change in self-care behavior, glycemic control, and perceived health functioning prior to and after insulin administration change will help elucidate these pathways.

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FIGURE 1.
Self-reported health response groups

FIGURE 2.

A and B, Box plot of A1c and Self Care inventory, respectively, by SRH; C, Bar chart of males in dark gray and females in light gray by SRH; D, Bar chart of insulin injection method with those on insulin injections in dark gray and those on a pump in light gray by SRH

FIGURE 3. Final path models with A1c as simple mediator between insulin administration, self-care behavior, sex, and SRH. * $P < .05$

TABLE 1

Participant demographics by total sample and insulin delivery method

Characteristic	Injectable (n = 37)	Pump (n = 47)	All (N = 84)	Injectable vs pump
Age, M (SD)	16.11 (2.00)	15.72 (2.11)	15.89 (2.06)	0.399
Sex, % (n)				
Female	62.2% (23)	44.7% (21)	52.4% (44)	0.066
Race ^{**} , % (n)				
Hispanic	51.4% (19)	44.7% (21)	47.6% (40)	0.005
African American	35.1% (13)	21.3% (10)	27.4% (23)	
White	8.1% (3)	29.8% (14)	2.2% (17)	
Asian	5.4% (2)	2.1% (1)	3.6% (3)	
Other	-	2/1% (1)	1.2% (1)	
A1c [*] , M (SD)	10.56 (2.26)	9.52 (2.05)	9.98 (2.19)	0.031
A1c [*] (mmol/mol)	91.89 (24.72)	80.57 (22.37)	85.55 (23.96)	
BMI, M (SD)	24.81 (5.17)	23.65 (4.13)	24.16 (4.62)	0.255
Household size [*] , M (SD)	3.68 (1.08)	4.22 (1.28)	3.98 (1.22)	0.044
Duration of illness, M (SD)	6.75 (3.78)	6.75 (3.63)	6.75 (3.68)	0.999
Self-care inventory, M (SD)	54.81 (15.05)	60.99 (16.35)	58.27 (16.00)	0.079
Self-rated health ^{**} , % (n)				
Poor/fair	62.2% (23)	29.8% (14)	44.1% (37)	0.003
Good/excellent	37.9% (14)	70.2% (33)	55.9% (47)	

Note: T-test (for continuous variables) and chi-square (for categorical variables) were used to detect significant differences participants on injectable or pump-delivered insulin;

* $P < .05$;

** $P < .01$.

Race was collapsed into Race: white vs not white.

TABLE 2

Logistic regression models with SRH as outcome variable

Predictor	OR	95% CI	P
Sex ^a	2.65	0.91, 7.69	.074
Self-care	1.37	0.78, 2.39	.271
Insulin delivery ^b	2.72	0.99, 1.06	.066
A1c	0.60	0.44, 0.82	.002

Note: Reference groups:^a = males;^b = pump, R^2 = .32 (Cox and Snell); .42 (Nagelkerke).