Assessing Measurement Invariance of the Diabetes Stress Questionnaire in Youth With Type 1 Diabetes

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Received April 22, 2014; revisions received August 15, 2014; accepted August 17, 2014

Objective To evaluate the factor structure and measurement invariance of the Diabetes Stress Questionnaire (DSQ), a measure of diabetes-specific stress, across sex, age (<9th grade vs. ≥9th grade), and glycemic control (optimal vs. suboptimal). Methods Data from 318 adolescent participants were pooled from four archival data sets and the ongoing Predicting Resiliency in Youth with Type 1 Diabetes study in which the DSQ was completed. Confirmatory factor and measurement invariance analyses were conducted to confirm the proposed factor structure and measurement invariance across sex, age, and glycemic control. Results The DSQ factor structure was found to have an acceptable fit, which was invariant across sex, age, and glycemic control. Conclusions When using the DSQ, differences in diabetes-related stress with respect to sex, age, or glycemic control can be considered meaningful. This study supports the DSQ as an evidence-based and well-established assessment of perceived diabetes stress in youth with type 1 diabetes.

Key words chronic illness; diabetes; endocrinology; statistical applications; stress.

Among children and adolescents in the United States, type 1 diabetes (T1D) is one of the most common chronic illnesses, with >15,000 new cases diagnosed every year (American Diabetes Association [ADA], 2013a; Centers for Disease Control and Prevention [CDC], 2013). If not managed properly, glycemic control will be affected, resulting in serious complications, including, but not limited to, heart disease, stroke, neuropathy, nephropathy, glaucoma, diabetic ketoacidosis, and death (ADA, 2013b). Risks of diabetes complications are reduced by following an intensive regimen, which requires individuals to monitor their diet, exercise regularly, test blood sugar levels numerous times per day, and either administer multiple insulin injections or use an insulin pump to adhere to a basal/bolus insulin regimen (National Diabetes Information Clearinghouse, 2014; Silverstein et al., 2005). Although diabetes management can be difficult at any age, it can be particularly challenging for adolescents with T1D (Greening, Stoppelbein, Konishi, Jordan, & Moll, 2007).

Multiple interacting factors influence diabetes outcomes such as glycemic control and quality of life, including access to medical care, parent education and involvement, and demographic characteristics (i.e., sex, age, etc.), among many others (Franklin et al., 2014; Naughton et al., 2014; Valenzuela et al., 2014). One explanation for the difficulties that adolescents experience with their diabetes management is the role of diabetes-specific stress (Malik & Koot, 2009; Smith et al., 2013). Based on Baum’s (1990) general definition of stress, diabetes-specific stress is defined here as a typically
negative experience that is accompanied by predictable biochemical, physiological, cognitive, emotional, and behavioral changes among individuals with diabetes that is directed toward altering or accommodating to the diabetes-specific stressor. Stress and coping are prominent in most theoretical models and conceptual frameworks focused on explaining the relations between various individual, social, familial, and environmental factors on diabetes outcomes (Bennett-Johnson, 1995; Gonder-Frederick, Cox, & Ritterband, 2002; Whittemore, Jaser, Guo, & Grey, 2010). Stressors (the perception or actual threat to an individual) and stress (the effect of this threat on an individual) are believed to exert both direct and indirect effects on glycemic control, mediated by such constructs as adherence, complexity of the medical regimen, family functioning, social competency, and self-efficacy (Bennett-Johnson, 1995; Gonder-Frederick et al., 2002; Whittemore et al., 2010). Stressors may impact glycemic control indirectly through behaviors related to medication regimen adherence, which in turn results in problems with glycemic control, and/or impact glycemic control directly via physiological arousal, insulin resistance, and increasing levels of hormones that affect blood glucose (Peyrot & McMurry, 1985).

Both theoretical (Bennett-Johnson, 1995; Gonder-Frederick et al., 2002; Whittemore et al., 2010) and empirical literature (Hains, Berlin, Davies, Parton, & Alemzadeh, 2006; Hains et al., 2007, 2009; Hanson, Henggeler, & Burghen, 1987) support the notion that perceived diabetes-related stress impacts glycemic control in adolescents with T1D. This impact may be more pronounced when the context and content of the stressors are considered more fully (Berlin, Hains, & Rabideau, 2012). For example, youth often identify more problems with diabetes self-care during social situations with friends and peers, whereas their parents identify the family context to be the most problematic (Berlin et al., 2006). It may be the case that socioecological factors, such as context of the environment (i.e., friend, peer, family, or school), moderate the relation between perceived diabetes stressors and glycemic control (Berlin et al., 2006, 2012; Hains et al., 2007, 2009). As such, it is potentially advantageous to transition from considering diabetes stress as a singular construct toward descriptions and assessments of diabetes stress that consider its numerous facets, including contextual factors (e.g., parent vs. peer stress), as well as the particular content of the stressor (e.g., adherence, diet, or hyperglycemia; Berlin et al., 2006; Delamater, Patino-Fernandez, Smith, & Bubb, 2012).

The Diabetes Stress Questionnaire (DSQ; Boardway, Delamater, Tomakowsky, & Gutai, 1993; Delamater et al., 2012) has been applied frequently in research and clinical settings to assess multiple types of diabetes-specific stressors and the contexts in which they occur (e.g., family, school, peers; Berlin et al., 2012; Delamater et al., 2012; Hains et al., 2006, 2007, 2009; Silverman, Hains, Davies, & Parton, 2003). One common usage of the DSQ is to explore how diabetes-specific stress functions differently across groups (i.e., male vs. female; younger vs. older youth). This research question assumes that the constructs measured by the DSQ are the same across these different groups being compared; however, this assumption has yet to be tested. It is important that the measure is statistically invariant across such groups to ensure that the measure is functioning the same way (Millsap, 2011). Therefore, any differences when comparing group means, correlations, and path coefficients can be attributed to actual differences between the groups. Without testing for invariance, parameter differences between the groups could be explained by differences in how the assessment instrument is measuring the construct, or how individuals are responding to various items, and renders any group differences equivocal.

By ensuring invariance of the DSQ, any group differences found in future research using the measure can be reliably assumed to result from actual differences between groups, and not simply artifacts of measurement differences across these different groups. Additionally, the DSQ may qualify as an evidence-based assessment (Holmbeck et al., 2008; Quittner, Modi, Lemanek, Ievers-Landis, & Rapoff, 2008), pending further exploration of the DSQ’s psychometric properties. The purpose of the present study is to first confirm the factor structure of the DSQ (Delamater et al., 2012) and then determine the extent to which the DSQ demonstrates measurement invariance across biological sex, age (<9th grade vs. ≥9th grade), and glycemic control (optimal vs. suboptimal). A secondary aim is to provide some cross-investigator evidence of validity and reliability of the DSQ to determine whether the DSQ qualifies as an evidence-based assessment measure.

**Methods**

**Participants**

Participant data were pooled from both an ongoing study and archival studies conducted since 2003. Data from 318 participants (53% female; 78% White/European American; \( M_{age} = 13.91, SD = 2.03 \)) were used, with 266 participants coming from four archival data sets (Data set 1: 45% female, 90% White/European American, \( M_{age} = 13.94, SD = 1.94 \); Data set 2: 60% female, 80% White/European American, \( M_{age} = 13.87, SD = 2.01 \); Data set 1.94).
3: 53% female, 88% White/European American, \(M_{\text{age}} = 13.58, SD = 2.31\); Data set 4: 80% female, 95% White/European American, \(M_{\text{age}} = 13.65, SD = 2.82\) and 52 participants coming from the ongoing Predicting Resiliency in Youth with Type 1 Diabetes (PRYDE) study (46% female, 39% White/European American, \(M_{\text{age}} = 14.33, SD = 1.62\)).

**Procedure**

Data from the PRYDE study participants were collected at a pediatric diabetes clinic, and institutional review board (IRB) approval was obtained from the necessary respective medical facility and university where the data were collected. Eligible participants <18 years of age gave assent, and their parents/legally authorized representatives (LARs) provided written informed consent. Eligible participants aged 18 years provided their own written informed consent. Archival data used for the present study were obtained from 266 participants with T1D who participated in one of four studies that were approved by the respective IRBs (Berlin et al., 2006; Hains et al., 2006, 2007, 2009). As with the PRYDE study, these data were primarily collected in person by researchers in clinical settings. With both the archival data and the PRYDE study, hemoglobin A1c (HbA1c) data were abstracted from the participants’ medical records at the same time as other data collection in clinic. Similar to the ongoing PRYDE study, parents/LARs provided informed consent for minors, and participants above the age of majority provided their own consent. Archival data were pooled from studies examining a social-information processing model in a diabetes-specific context—specifically, how negative attributions of others affected glycemic control through the constructs of anticipated adherence difficulties and diabetes-related stress.

**Measures**

**Demographics**

For the purpose of the present study, demographics relating to sex, age, and glycemic control were all collected (see Table I).

**Diabetes Stress Questionnaire**

The DSQ is a 65-item, self-report measure used to assess for diabetes-related stressors. It has a second-order factor structure, with eight subscales used to compute a total diabetes-related stress score. The eight subscales are Distress-Worry, Peer Stress, Averse Interpersonal Effects, Parental Stress, Hyperglycemia, Self-Care Regimen, Diet, and Hypoglycemia (Delamater et al., 2012). The Distress-Worry factor is composed of 13 items (e.g., “Feeling like there’s too much to do to keep my diabetes in good control”); the Peer Stress factor is composed of eight items (e.g., “Testing my blood when friends are with me”); the Averse Interpersonal Effects factor is composed of nine items (e.g., “Feeling that people treat me differently because they know I have diabetes”); the Parental Stress factor is composed of seven items (e.g., “My parents reminding or nagging me about testing my blood or urine”); the Hyperglycemia factor is composed of eight items (e.g., “Being in the hospital for ketoacidosis”); the Self-Care Regimen factor is composed of eight items (e.g., “Writing down the results of blood and urine tests; keeping good records”); the Diet factor is composed of five items (e.g., “Not being able to eat foods that my friends can eat”);
and the Hypoglycemia factor is composed of three items (e.g., “Getting symptoms of low blood sugar like shakiness, sweating, hunger or headache”). Four of the 65 items do not significantly load on any of the eight factors (Delamater et al., 2012). Responses to the DSQ are on a 4-point Likert scale (not at all, a little, pretty much, very much). The DSQ has been found to have excellent internal consistency (α = .97; Boardway et al., 1993) and evidence criterion validity when evaluated using measures of negative attributions of friend reactions to one’s diabetes (r = .28, p < .01) and anticipated adherence difficulties (r = .40, p < .0001; Hains et al., 2006).

Hemoglobin A1c (HbA1c)
HbA1c is a measure of average blood glucose over the past 3 months for most individuals and has long been used as a proxy for overall glycemic control (ADA, 2013b; Dagogo-Jack, 2010). HbA1c was obtained from medical records at the time of participation (M$_{HbA1c}$: Data set 1 = 8.6%, SD = 1.4%; Data set 2 = 8.3%, SD = 1.4%; Data set 3 = 9.0%, SD = 1.5%; Data set 4 = 8.1%, SD = 1.1%; Data set 5 = 10.8%, SD = 2.6%). Age-specific HbA1c cutoffs were determined using the standards set by Silverstein et al. (2005). Suboptimal glycemic control was marked by HbA1c levels ≥8.0% for participants aged ≤12 years, and marked by HbA1c levels ≥7.5% for participants aged ≥13 years.

**Analytic Plan**
The first objective was to confirm the factor structure of the DSQ (Delamater et al., 2012). Although the DSQ has a second-order factor structure, for the purposes of the present study it was modeled as a first-order factor structure of the subscales using individual DSQ items as indicators. Confirmatory factor analysis (CFA) was used to confirm the established factor structure in *Mplus 7.11* using the weighted least squares parameter estimates (Asparouhov & Muthén, 2010) and the delta parameterization to account for missing data and the nonnormal ordinal response format of the DSQ (Muthén & Muthén, 1998–2012). The model fit was evaluated using the comparative fit index (CFI) and root mean square error of approximation (RMSEA), with CFI values ≥0.95/≥0.90 considered good/acceptable fit, and RMSEA values <0.05 and <0.08 considered good to acceptable (Hu & Bentler, 1999). Previous Monte Carlo studies suggest that the current sample size of 318 was sufficiently powered to evaluate the hypothesized measurement models (Wolf, Harrington, Clark, & Miller, 2013).

After confirming the proposed factor structure of the overall model, the extent to which the DSQ was assessing the same constructs across groups based on sex, age, and glycemic control was determined. The measurement invariance analyses require a binary or nominal grouping variable. Based on the aforementioned diabetes psychosocial models, which include diabetes-specific stress (Bennett-Johnson, 1995; Gonder-Frederick et al., 2002; Whittemore et al., 2010), it was hypothesized that sex, age (i.e., older/high school vs. younger/middle school), and level of glycemic control (i.e., optimal vs suboptimal) would all affect the amount and measurement of diabetes stress experienced by youths. Grade level (<9th grade vs. ≥9th grade) was chosen instead of chronological age to divide participants because it serves as a representative proxy for academic milieu and is more indicative of developmental differences. A shift from being parent and adult focused in middle school to more peer focused often occurs in high school and adolescence (Fulghini, Barber, Eccles, & Clements, 2001). Because of the important role that peers have been found to play in adherence behaviors in adolescents with T1D (Hains et al., 2006, 2007), it was reasoned that the division between middle school and high school to be more salient than actual chronological age. To test this impact, increasingly restrictive invariance analyses were conducted to test for configural, metric, and scalar invariance (described below).

To test the measurement invariance of the DSQ, multigroup CFA was used. As mentioned previously, the DSQ was modeled as a first-order factor structure with the item indicators for each of the eight subscales, to ensure that the DSQ was invariant at the subscale level. According to the recommendations of Cheung and Rensvold (2002), the change in the CFI was used to assess for invariance, given that the chi-square difference test between two nested models is often overly sensitive to sample size, and may capture statistically—but not clinically significant—differences in groups (Brannick, 1995; Cheung & Rensvold, 2002; Kelloway, 1995). Scaled chi-square difference tests were reported for completeness. These difference tests provide comparisons of increasingly stringent nested models (i.e., scalar invariance model vs. metric invariance model; metric invariance model vs. configural invariance model; Muthén & Muthén, 1998–2012). To be considered invariant across groups, the decrease in CFI must be ≤–0.01 from each level of invariance testing (i.e., configural to metric, metric to scalar).

**Configural Invariance**
Configural invariance is the least stringent of the three forms of invariance tested. It is used to determine if the groups being compared have the same factor structure (i.e., same number of factors and the same items), and if the
same common factors are related with the same items across groups (Gregorich, 2006). Configural analyses comprise an initial step in invariance testing, whereas later, more stringent tests (i.e., metric and scalar) are necessary to determine if a measure is truly invariant. Mplus tests a CFA model with ordinal indicators by (1) freeing all factor loadings for each item across groups; (2) freeing all thresholds for each item across groups; (3) fixing all scale factors for each item at one for all groups; (4) fixing all factor means at zero for each item for all groups; and (5) freeing all factor variances for each item across groups (Muthén & Muthén, 1998–2012). Thresholds are the expected value of the standardized variable when an individual moves from one category to the next (Millsap & Yun-Tein, 2004). The number of thresholds for a variable is always one less than the actual number of responses for that variable. In the case of the DSQ, because each item has four total response options, each item has three thresholds—namely, the expected value at which a participant transitions from a score of 0 (not at all) to 1 (a little), 1 (a little) to 2 (pretty much), or 2 (pretty much) to 3 (very much).

Metric Invariance
Sometimes referred to as weak invariance, metric invariance is used to determine if the comparison of factor variances and covariances are meaningful. This is done by determining whether items of the measure have the same factor loadings in both groups, and whether the common factors have the same meaning across different groups (Gregorich, 2006). This is done in Mplus by (1) constraining factor loadings for all items to be equal across groups; (2) holding the first threshold of each item equal across groups and holding the second threshold equal across groups for the items used to set the metric of the factors; (3) fixing the scale factors at one in one group and freeing the scale factors in the other group; (4) fixing the factor means to be zero in one group and freeing the factor means in the other group; and (5) freeing the factor variance across groups (Muthén & Muthén, 1998–2012).

Scalar Invariance
Scalar invariance, or strong invariance, is used to determine if the comparison of factor and observed group means is meaningful. In the case of continuous outcome variables, this analysis determines whether the groups share the same item intercepts (Gregorich, 2006). However, when the outcome variables are categorical (as is the case with the DSQ), this analysis determines whether the thresholds of the items are equal. This is done in Mplus by (1) constraining the factor loadings of each item to be equal across groups; (2) constraining the thresholds of each item to be equal across groups; (3) fixing the scale factors for each item at one in one group, and freeing the scale factors in another group; (4) fixing the factor means at zero in one group, and freeing the factor means in the other group; and (5) freeing the factor variance for each item across groups (Muthén & Muthén, 1998–2012). Readers interested in a more detailed introduction to measurement invariance are encouraged to consult Gregorich (2006).

Reliability and Validity
In addition to the factor and invariance analyses, reliability and validity analyses were performed to help establish the DSQ as an evidence-based assessment (Holmbeck et al., 2008). The internal consistency of the DSQ was calculated using Cronbach’s alpha (Cronbach, 1951) for each of the eight subscales, as well as for the total score. Both the convergent and criterion validity of the measure were assessed (Campbell & Fiske, 1959). Convergent validity was determined by comparing the correlations among the subscales of the DSQ with one another, with the expectation that they will all be significantly correlated. Criterion validity of the measure was determined by comparing the subscales and total score of the DSQ with participants’ HbA1c levels, as it is expected that diabetes stress would act as a predictor of glycemic control.

Results
The initial CFA across all participants yielded an acceptable model fit with a CFI of 0.920 and an RMSEA of 0.048 (see Table II). Although the CFI value is less than optimal (>0.95), it is still an acceptable fitting model for the factor structure proposed by Delamater and colleagues (2012). This fit met the requirements to proceed forward with invariance analyses.

Sex
As shown in Table II, the configural model had an acceptable fit across sex at the configural level. In comparing the configural to metric model across sex, a nonsignificant change in chi-square was found ($\Delta \chi^2 = 59.390$, $p > 0.1$). In addition, an improved fit was demonstrated by an increase in the CFI, indicating that, across sex, the DSQ is invariant from configural to metric. Based on both the RMSEA and CFI, the DSQ had a better model fit at the metric level than at the configural level. In comparing the metric to scalar model, a significant change in chi-square was found ($\Delta \chi^2 = 243.631$, $p < .001$), indicating a worsening of model fit. However, the RMSEA remained constant at the scalar level, with a negligible decrease in the CFI (<−0.01). This indicates that although a slightly
worse model fit was found at the scalar level (when compared with the metric level), it still improved from configural and remained within the acceptable range. Based on the standards of Cheung and Rensvold (2002), these data meet criteria for invariance from metric to scalar across sex (see Table II).

**Age (Older/High School Vs. Younger/Middle School)**

Based on the CFI and RMSEA, the DSQ displayed the best model fit across age at the configural level. Despite the slight worsening in model fit, all values (configural, metric, and scalar) met criteria for an acceptable model fit. Significant changes in chi-square were found comparing both the configural versus metric models ($\Delta \chi^2 = 216.615, p < .001$) and metric versus scalar models ($\Delta \chi^2 = 333.824, p < .001$) across age. However, the decrease in CFI was found to be $< -0.01$ for both configural to metric and from metric to scalar, indicating that the DSQ is invariant across age (see Table II).

**Optimal Versus Suboptimal HbA1c**

Across the two categories of HbA1c (optimal vs. suboptimal), the DSQ displayed an acceptable model fit at the configural level based on CFI and RMSEA values. Comparing the configural to metric model, a significant change in chi-square was found ($\Delta \chi^2 = 206.646, p < .001$). However, the CFI increased from configural to metric, indicating an improvement in model fit at the metric level, and confirming that the DSQ is invariant across HbA1c categories for configural to metric. At the scalar level, a consistent RMSEA and slight decrease in the CFI indicated a worsening of model fit, though still considered acceptable based on these values. A significant change in chi-square was found ($\Delta \chi^2 = 180.919, p < .001$) when comparing the metric to scalar models. However, because the decrease in CFI was found to be $< -0.01$, the DSQ is considered to be invariant across HbA1c categories (see Table II).

**Reliability and Validity**

The DSQ displayed good internal consistency (Nunnally & Bernstein, 1994; Streiner, 2003), with all alpha values of the subscales and total score $> .7$ ($\alpha$ values ranging from .708 to .965; see Table III). Furthermore, the DSQ was found to have good convergent validity, as all eight subscales correlated significantly with one another ($r$ ranging from .462 to .768; see Table III). The total DSQ score, as well as seven of the eight subscales, was found to be predictive of glycemic control, with all the subscales being significantly correlated with HbA1c ($r$ values ranging from .182 to .366; see Table III), excluding Hypoglycemia.

**Discussion**

The DSQ (Boardway et al., 1993) is used as a self-report measure of diabetes-specific stressors (Delamater et al., 2012; Hains et al., 2006, 2007, 2009) and carries the advantage of tapping into both the context and content of perceived stressors. The purpose of the present study was to more thoroughly investigate the psychometric properties of the DSQ by first confirming its factor structure, and then determining its invariance across sex, age, and glycemic control. The present study found the DSQ to have an acceptable factor structure and to be invariant across the domains of sex, age, and glycemic control.

Although often overlooked, measurement invariance is an important aspect of most research examining group differences. Any type of research using questionnaires to assess for group differences of a construct (i.e.,
correlations, t tests, etc.) assumes that the measures are invariant across said groups (Gregorich, 2006). Despite the importance of testing for invariance, it is often assumed rather than tested. Without empirically demonstrating that an assessment instrument is invariant, it cannot be assumed that any group differences found are actually due to true differences between the groups being compared. Rather, these differences between groups may be better accounted for by inconsistencies in the construct being assessed by the measure.

In using the change in CFI cut-off criteria outlined by Cheung and Rensvold (2002), the present study found the DSQ to be invariant across sex, age, and glycemic control. This finding contributes meaningfully to the utility of the measure, as the DSQ is an instrument used in research assessing for diabetes-related stress in children and adolescents (Delamater et al., 2012). In particular, finding the DSQ to be invariant at the metric and scalar levels allows for defensible comparisons of factor variances, covariances, observed means, and factor means across sex, age (8–18 years), and glycemic control (Gregorich, 2006). Research suggests that diabetes-related stress may play an important role in diabetes-related outcomes, such as adherence to a medical regimen, glycemic control, and quality of life (Bennett-Johnson, 1995; Gonder-Frederick et al., 2002; Hains et al., 2006; Whittemore et al., 2010). As such, this knowledge is important and useful to the development of outcome measures for interventions aimed at decreasing diabetes-specific stress. Knowing that group differences (among sex, age, and glycemic control levels in diabetes-related stress) are meaningful could indicate that tailoring clinical interventions based on these found group differences may be worthwhile.

The present study contributes further evidence supporting the DSQ as a well-established evidence-based assessment (Holmbeck et al., 2008). Three criteria must be met for an assessment tool to meet the specifications of a well-established evidence-based assessment: 1) the measure must have been presented in at least two peer-reviewed articles by different investigators or investigatory teams; 2) sufficient detail about the measure to allow critical evaluation and replication (e.g., measure and manual provided or available upon request); 3) detailed (e.g., statistics presented) information indicating good validity and reliability in at least one peer-reviewed article (Holmbeck et al., 2008, p. 960).

The DSQ has met the first criterion by multiple peer-reviewed reports (Delamater et al., 2012; Hains, Davies, Parton, & Silverman, 2001; Hains et al., 2006, 2007, 2012).

### Table III. Correlations Between the Diabetes Stress Questionnaire Subscales, Total Score, and HbA1c

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>DW</th>
<th>Peer</th>
<th>AIE</th>
<th>Parent</th>
<th>Hyper</th>
<th>SCR</th>
<th>Diet</th>
<th>Hypo</th>
<th>HbA1c</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$\alpha = .965$</td>
<td>$\alpha = .903$</td>
<td>$\alpha = .827$</td>
<td>$\alpha = .851$</td>
<td>$\alpha = .837$</td>
<td>$\alpha = .806$</td>
<td>$\alpha = .727$</td>
<td>$\alpha = .708$</td>
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<tr>
<td>Total</td>
<td>1.415</td>
<td>0.029</td>
<td>0.161*</td>
<td>0.009**</td>
<td>$-0.071^{**}$</td>
<td>0.006**</td>
<td>0.093**</td>
<td>$-0.014^{**}$</td>
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<td>(1.416)</td>
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<td>Distress-worry</td>
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<tr>
<td>(DW)</td>
<td>2.302</td>
<td>0.643</td>
<td>0.743</td>
<td>0.716</td>
<td>0.719</td>
<td>0.768</td>
<td>0.718</td>
<td>0.555</td>
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<td>Peer stress (Peer)</td>
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<td>(AIE)</td>
<td>1.904</td>
<td>0.501</td>
<td>0.467</td>
<td>0.493</td>
<td>0.631</td>
<td>0.579</td>
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<td>1.941</td>
<td>0.659</td>
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<td>0.508</td>
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<td>Averse interpersonal effects</td>
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<td>Parental stress (PaS)</td>
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<td>(Hyper)</td>
<td>2.275</td>
<td>0.711</td>
<td>0.651</td>
<td>0.513</td>
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<td>Hyperglycemia</td>
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<tr>
<td>(Hyper)</td>
<td>2.283</td>
<td>0.655</td>
<td>0.590</td>
<td>0.571</td>
<td>0.309</td>
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<td>(0.692)</td>
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<td>Self-care regimen</td>
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<td>(SCR)</td>
<td>2.091</td>
<td>0.583</td>
<td>0.496</td>
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<td>(0.647)</td>
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<td>(Hypo)</td>
<td>2.066</td>
<td>0.495</td>
<td>0.197</td>
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<td>Hypoglycemia</td>
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<tr>
<td>(Hypo)</td>
<td>2.237</td>
<td>$-0.002^{**}$</td>
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<td>(0.810)</td>
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<td>(1.859)</td>
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Note. All values above the diagonal are significant at $p < .05$ unless denoted by ns. Diagonal of table provides means (and standard deviations).
2009; Silverman et al., 2003; Boardway et al., 1993) and the second criterion by the measure items being readily available (Delamater et al., 2012). With regard to the final criterion, limited data pertaining to the DSQ’s reliability and validity have been presented in the past (Boardway et al., 1993; Delamater et al., 2012), and no known studies have replicated or confirmed the DSQ factor structure that was developed using exploratory factor analyses. However, the present study (1) adds extensive detail about the statistics supporting the criterion validity of using the DSQ as a measure of diabetes perceived stress; (2) confirms the proposed factor structure; and (3) provides evidence that this factor structure is invariant across sex, age, and level of glycemic control.

**Methodological Limitations**

Despite this study’s strengths, there are some limitations that need to be addressed. First, it is important to acknowledge the limited diversity of race/ethnicity in the sample, even though it closely reflects a large contemporary report of North American youth with T1D (CDC, 2011). More specifically, the present sample used is comparable with a recent report of U.S. national prevalence rates with respect to proportion of diagnosed Caucasian youth (Dabelea et al., 2014), a higher proportion of African American youth, and an underrepresentation of Latino(a) and Asian-American youth. Because of the disproportionality high within sample number of Caucasian or European American participants, this study was not sufficiently powered to conduct invariance analyses across racial or ethnic groups. Research suggests that health disparities exist between racial and ethnic T1D groups in the domain of glycemic control (Auslander, Thompson, Dreitzer, White, & Santiago, 1997; Cohen, Lumley, Naar-King, Partridge, & Cakan, 2004; Delamater, Albrecht, Postellon, & Gutai 1991; Delamater et al., 1999). Future work across racial and ethnic groups is vital not only to validate the DSQ to compare differences in diabetes stress among these disparate groups but also to identify factors that buffer or exacerbate these disparities and to test interventions for resolving these disparities. Efforts to examine diabetes-related stress as a possible mechanism contributing to these disparities would be enhanced by testing the DSQ for potential racial and ethnic measurement invariance in larger future studies.

Another potential limitation of the present study is the correlations between the subscales of the DSQ and HbA1c. Although all the subscales (excluding Hypoglycemia) are statistically significantly correlated with glycemic control, these correlations could be considered to be clinically weak (all \( r \) values \( \leq .366 \)). In examining the measure’s criterion validity, the correlations between HbA1c with the Averse Interpersonal Effects \( (r = .182) \) and Diet \( (r = .197) \) subscales were found to be particularly small. This point should be considered when making any clinical interpretations of these results, and determining which areas of diabetes-related stress (as indicated by the subscales) are most salient to target in intervention development.

Furthermore, this study’s use of both an ongoing study and multiple archival data sets results in a number of limitations. First and foremost, there is the potential for differences in the diabetes care received by participants that may contribute to their stress. As all studies were conducted between 2003 and 2014, they all occurred after The Diabetes Control and Complications Trial (The Diabetes Control and Complications Trial Research Group, 1993); however, there have been significant advances in diabetes care, technologies, and clinical approaches between 2003 and 2014. As many of these advances (e.g., pumps and continuous glucose monitoring) improve stress and quality of life in youth with diabetes and their parents, these advancements may impact participants’ score on the DSQ. In addition, the use of archival data limited the other measures that were available for testing convergent validity. As such, the subscales of the DSQ had to be used. It is recommended that future research further evaluate the convergent validity of the DSQ using other related measures.

**Conclusions**

The present study is important to the diabetes literature and the area of pediatric psychology for a number of different reasons. First and foremost, it indicates that the DSQ appears to be invariant across sex, age, and glycemic control. By showing the invariance of DSQ across these groups, future research can reliably use the DSQ in studies comparing group differences in diabetes-specific stress. Furthermore, the present study helps to establish the DSQ as an evidence-based assessment, which is needed in the field of pediatric psychology. Establishing the DSQ as an evidence-based assessment may catalyze development of meaningful outcome assessments for clinical and research interventions in youth with T1D.

**Funding**

This work was supported in part by a grant from The University of Memphis Faculty Research Grant Fund to KSB; and by the University of Wisconsin-Milwaukee Research Growth Initiative (to AAH). This support does
not necessarily imply endorsement by the University of Memphis research conclusions.

Conflicts of interest: None declared.

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