Cognitions Associated With Hypoglycemia Awareness Status and Severe Hypoglycemia Experience in Adults With Type 1 Diabetes

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Diabetes Care 2019;42:1854–1864 | https://doi.org/10.2337/dc19-0002

OBJECTIVE

Impaired awareness of hypoglycemia (IAH) and recurrent severe hypoglycemia (RSH) remain problematic for people with type 1 diabetes (T1D), despite major therapeutic advances. We explored beliefs around hypo- and hyperglycemia in adults with T1D with, and without, IAH and RSH.

RESEARCH DESIGN AND METHODS

A cross-sectional U.S. multicenter survey included Attitudes to Awareness of Hypoglycemia (A2A; a 19-item questionnaire concerning beliefs about hypoglycemia), the Gold score (single item: awareness of hypoglycemia), and a question about severe hypoglycemia over the preceding year. The survey was emailed to 6,200 adult participants of the annual T1D Exchange clinic registry data collection. A2A data were subjected to principal component analysis with varimax rotation.

RESULTS

Among 1,978 respondents (response rate 32%), 61.7% were women, mean ± SD age was 39.6 ± 16.3 years, and T1D duration was 23.1 ± 13.8 years. Thirty-seven percent reported IAH, 16% RSH, and 9% both. A2A items segregated into three factors, differently distributed by hypoglycemia experience. Respondents with IAH or RSH expressed appropriate concern about hypoglycemia, but those with IAH were more likely to prioritize hyperglycemia concerns than those with intact awareness (P = 0.002). Those with RSH showed greater normalization of asymptomatic hypoglycemia than those without (P = 0.019) and trended toward prioritizing hyperglycemia concerns (P = 0.097), driven by those with both IAH and RSH.

CONCLUSIONS

Adults with T1D with IAH and RSH report specific cognitions about hypoglycemia and hyperglycemia, which may act as barriers to hypoglycemia avoidance and recovery of awareness. These may be modifiable and present a target for enhancing engagement of vulnerable people with strategies to avoid future hypoglycemia.

Severe hypoglycemia (SH) is a serious complication of insulin treatment for type 1 diabetes (T1D). It is associated with cognitive impairment and can lead to confusion, unusual behavior, coma, seizure, cardiac arrhythmia, and impaired quality of life (1,2). SH accounts for between 4 and 10% of deaths in people with T1D under 40 years of age

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Received 1 January 2019 and accepted 13 July 2019

This article contains Supplementary Data online at http://care.diabetesjournals.org/lookup/suppl/doi:10.2337/dc19-0002/-/DC1.

(3). Its incidence has been described as ~1.3 episodes per adult with T1D per year, but its distribution is skewed, with ~60% of people free from SH in any 1 year and 10% of the population experiencing ~70% of all episodes (4). Glycated hemoglobin (HbA_{1c}), an accepted measure of glucose control, does not reveal hypoglycemic risk, with SH experienced by ~25% of adults with T1D regardless of their HbA_{1c} (5,6).

Repeated exposure to hypoglycemia leads to impaired awareness of hypoglycemia (IAH) (7). Awareness of hypoglycemia should prompt an individual to take appropriate action to restore blood glucose early in hypoglycemia. Thus, IAH is one of the main risk factors for SH, increasing the risk more than fivefold (5,8–10). In research studies, IAH has been reversed by avoidance of exposure to blood glucose <54 mg/dL (11–13). Restoration of awareness of hypoglycemia in clinical practice is more challenging. Following the pathway for the management of hypoglycemia in T1D (14), some people regain awareness with educational and psychoeducational programs such as Dose Adjustment For Normal Eating (DAFNE) and HypoCOMPaSS (15,16), yet others continue with IAH and SH (9). Despite evidence for benefit from technologies such as insulin pumps linked to glucose sensors for reducing SH (17,18), people with problematic hypoglycemia may not always be willing to use or able to obtain benefit from these, even when available (14,19–21).

There is growing qualitative evidence that certain beliefs or cognitions (e.g., lack of concern about hypoglycemia and/or a heightened perception of threat associated with hyperglycemia) may serve as barriers to a person's ability to prevent SH (22,23). The study by Anderbro et al. (24) found a disconnect between hypoglycemia concern and risk of SH. Notably, 32% of those at high risk of SH expressed low concern about hypoglycemia. In another study, people with IAH were less likely to enact agreed changes to their insulin regimens than those with intact awareness (19).

The Attitudes to Awareness of Hypoglycemia (A2A) questionnaire was developed from qualitative research by Rogers et al. (22) into beliefs about hypoglycemia in people with T1D experiencing recurrent SH (RSH) in the U.K. The questionnaire assesses the degree to which individuals endorse a range of potentially modifiable attitudes or beliefs implicated in problematic hypoglycemia. The aim of this study was to investigate the prevalence of such beliefs and their association with current experience of SH and IAH in a U.S. population of adults with T1D.

RESEARCH DESIGN AND METHODS

We conducted a cross-sectional U.S. multicenter online survey of adults with T1D who completed a questionnaire about hypoglycemia as part of the T1D Exchange clinic registry annual data collection. Established in 2010 and coordinated by the Jaeb Centre for Health Research, the Registry has enrolled participants with a diagnosis of T1D from >75 clinical centers throughout the U.S. (25). On enrollment, participants complete a questionnaire and permit access to their medical records. Additional data are collected annually from registered participants who respond to an e-mail invitation.

Our questionnaire was distributed in the 2017 annual electronic questionnaire packet to 6,200 adults who were enrolled in the Registry at a current clinical center, had stated a preference to be contacted about T1D Exchange studies, had a valid e-mail address, were aged 18–90 years, did not need to be reconsented due to becoming 18 years old, and had completed the enrollment questionnaire at least 9 months before. Potential participants were excluded if they had received a pancreas or islet cell transplant. The solicitation e-mail did not refer to cognitions about hypoglycemia but simply invited participants to complete a questionnaire about how they manage T1D.

Measures

Part 1 of the A2A assesses beliefs about awareness of hypoglycemia and motivation of those with IAH to regain awareness. Part 2 comprises 12 attitudinal statements reflecting (potentially unhelpful) beliefs about hypoglycemia, to which respondents rate their level of agreement on a Likert scale from 0 (not at all true) to 3 (very true). For example, "I don't believe I'll have a severe hypoglycemia episode in the future," and "I don't need to treat low blood glucose, unless I feel symptoms." Two additional statements check accuracy of the individual's perception of their own risk: item 9, "I don't need to worry about hypoglycemia because I don't get low blood glucose very often," and item 13, "I'm not too bothered about warning signs because severe hypoglycemia is rare for me." Questionnaire items were informed by qualitative analysis of semistructured interviews with people with T1D and IAH in the U.K. (22) and cognitively debriefed with six of those participants to ensure clarity and appropriateness.

Minor modifications were made to the original A2A questionnaire to ensure cultural appropriateness. The questionnaire was reviewed by the T1D Exchange Operations Committee and the T1D Exchange Steering Committee. Spelling was adjusted and some language modified for cultural fit. For example, "(Treating hypoglycemia when I don't have symptoms) is an unnecessary fuss" became "...is a bother to me." Blood glucose units were converted to milligrams per deciliter. Hypoglycemia was explicitly defined for this study as a blood glucose <55 mg/dL.

Awareness of hypoglycemia was assessed using the Gold score, a single item to which respondents rate their awareness from 1 (I am always aware) to 7 (I am never aware). A score of ≥4 is considered IAH (10).

Frequency of SH was determined with a question referring to the American Diabetes Association definition of SH (1): "How many episodes of hypoglycemia have you had in the last 12 months for which you were not able to treat yourself? (You had to have treatment from someone else, lost consciousness or had a seizure)," to which respondents selected a value from 0 to 19 or >19. RSH was defined as ≥2 self-reported episodes of SH in the past year, consistent with established definitions of problematic hypoglycemia (14).

HbA_{1c} was the latest available in participants' clinical records; demographic and other clinical data were collected via the online survey.

Data Preparation and Analysis

There were no missing nondiscretionary data, as the electronic questionnaire mandated completion of all such items before it could be submitted. Gold score responses were checked for consistency with responses to the two A2A items that define IAH and "At what blood glucose level do your symptoms of hypoglycemia

usually occur?" Inconsistent responses were compared with free-text comments. For the current analysis, IAH was determined by two or more responses being positive for IAH (i.e., Gold score of ≥4; "yes"; and "<55 mg/dL" or "I do not get symptoms when my blood glucose is low"), if this was consistent with free-text. This allowed for participants making an error in a single item response. If responses and free-text comments were inconsistent, the participant was removed from the analysis on the basis that reliable classification was impossible.

Structural validity of the A2A was examined using exploratory factor analysis. The Kaiser-Meyer-Olkin statistic of 0.723 indicates that the sample size was adequate (26). The Bartlett test of sphericity χ^2 (df 66) was 2,234.34 ($P < 0.001$), indicating that items were related. Thus, principal component analysis with orthogonal (varimax) rotation was used. Decisions about how many factors to retain were informed by Kaiser eigenvalues (>1) (27), percentage variance explained by each factor, and factor loadings. Contemporary recommendations are that factor loadings ≥0.5 indicate strong and stable factors (28). However, the significance of factor loadings depends on the sample size (29). Thus, we were able to accept factor loadings ≥0.3 in which items were considered meaningful and justifiably relevant to the factor, so as not to compromise the face and content validity of the A2A. Cronbach α was used to assess internal consistency reliability of the identified factors (scales).

The comparison of interest was beliefs about hypoglycemia and hyperglycemia in those affected by problematic hypoglycemia versus those unaffected. We defined problematic hypoglycemia as either IAH or RSH. Mann-Whitney *U* tests were used to compare A2A scale scores by level of hypoglycemia awareness (intact vs. impaired), presence of RSH (RSH vs. ≤1 SH episode), and education status (university degree vs. no degree, the latter covering all education from seventh grade to college attendance with no degree). Responses to individual items by awareness status and experience of SH were compared with independent-samples *t* tests. Finally, we correlated A2A scale scores with HbA_{1c} as a continuous variable using the Spearman rank correlation coefficient. Data were analyzed with SPSS version 24 (IBM, 2016).

Data and Resource Availability

The A2A is the copyright of King's College London. It is available free of charge to academic researchers, clinicians, and students for use in noncommercially funded research. For commercially funded studies (initiated or sponsored by industry), a license fee will apply. Potential users are advised to e-mail stephanie.amiel@kcl.ac.uk to enquire about or access the latest version of the questionnaire and scoring guidance.

RESULTS

A total of 1,978 responses were received, a response rate of 32%. Five respondents gave inconsistent responses to the three items about hypoglycemia awareness. Of these, four could be reliably classified: three as IAH (one who attributed perceived awareness to the use of continuous glucose monitoring [CGM]; one who identified him/herself as aware but whose responses to the Gold score, glucose concentration for awareness, and free-text comments were consistent with IAH; and one who consistently indicated IAH except the Gold score), and one as aware, who consistently indicated awareness in question responses and free-text comments except for the glucose concentration question. Only one respondent with inconsistent responses could not be reliably classified and was excluded, leaving 1,977 responses for analysis.

Respondents were more likely to be women (62% vs. 51%; $P < 0.001$), to be older (mean age 40 vs. 38 years; $P = 0.0019$), and to have had diabetes longer (mean 23 vs. 21 years; $P \leq 0.001$) compared with nonrespondents. Respondents were also more likely to be of white, non-Hispanic ethnicity ($\chi^2 = 30.58$; $P < 0.001$). There were no differences in proportions with private health insurance, other insurance, or no insurance ($\chi^2 = 0.6625$; $P = 0.718$).

Demographics

Demographic and clinical characteristics of the sample are shown in Table 1, for the whole group and stratified by awareness status and RSH experience. As shown in Fig. 1, 447 (23%) of respondents experienced at least 1 SH episode during the past year, ranging from 0 to >19 episodes per person per year, with 47 (2.4%) respondents experiencing ≥16 episodes. Thirty-seven percent reported IAH, 25% of whom reported RSH, whereas only 11% of those with intact awareness had experienced RSH in the year.

Educational attainment for the whole population was high, with 98.2% having obtained a high school diploma or higher and 58.4% a bachelor's degree or higher. Those using CGM had higher educational attainment than those not ($U = 347{,}029.5$; $z = -8.87$; $P < 0.001$). There was no difference in educational attainment by awareness of hypoglycemia, but those with RSH reported lower educational attainment ($U = 203{,}527.5$; $z = -4.367$; $P < 0.001$) than those without.

HbA_{1c} was obtained with a median time between measurement and questionnaire completion of 177 days (interquartile range 77–256). Respondents with IAH were older, were more likely to be women, and had longer diabetes duration, lower mean HbA_{1c}, and greater use of insulin pumps and CGM than those with intact awareness of hypoglycemia. Respondents with RSH had longer duration of diabetes, had higher mean HbA_{1c}, checked blood glucose more frequently, and had lower rates of insulin pump and CGM use than those without RSH.

A2A: Scale Structure and Reliability

Exploratory factor analysis revealed the 12 part 2 A2A items loaded onto 4 factors, explaining 50.2% of the cumulative variance. Parallel analysis with random data values confirmed retention of three factors, explaining 41.6% of the variance. Therefore, a forced three-factor analysis was applied, yielding three potential four-item scales (Table 2), each named according to the theme of their constituent items: Asymptomatic Hypoglycemia Normalized; Hypoglycemia Concerns Minimized; and Hyperglycemia Avoidance Prioritized.

Cronbach α coefficients were deemed adequate (α = 0.46–0.51), indicating reasonable consistency reliability for these brief four-item scales.

Differences in Beliefs Between Those With and Without Problematic Hypoglycemia

Table 3 shows A2A mean scale scores and individual item response frequencies by awareness status and SH frequency. Compared with respondents with intact awareness, those with IAH minimized

Table 1—Demographic and clinical characteristics for the whole sample and stratified by awareness status and frequency of SH

	All respondents	Awareness status			Frequency of SH				
		IAH	Aware	*P* value IAH vs. Aware	No SH	Any SH (≥1 episode in past 12 months)	*P* value Any SH vs. No SH	RSH (≥2 episodes in past 12 months)	No RSH	*P* value RSH vs. No RSH
n (%)	1,977 (100)	728 (38.8)	1,249 (63.2)		1,530 (77.4)	447 (22.6)		323 (16.3)	1,654 (83.7)	0.001
Age (years)	39.6 ± 16.3	44.3 ± 16.8	36.9 ± 15.4	<0.001	39.32 ± 16.3	40.58 ± 16.4	0.155	40.82 ± 16.9	39.37 ± 16.2	0.156
Duration of diabetes (years)	23.1 ± 13.8	27.0 ± 14.8	20.8 ± 12.5	0.001	22.2 ± 13.2	26.2 ± 14.7	<0.001	25.8 ± 14.9	22.55 ± 13.5	<0.001
HbA_{1c}, % (mmol/mol)	7.8 ± 1.56 (62 ± 16.3)	7.65 ± 1.44 (60 ± 15.7)	7.88 ± 1.52 (63 ± 16.6)	0.004	7.71 ± 1.38	8.10 ± 1.80	<0.001	8.14 ± 1.72	7.73 ± 1.43	<0.001
Sex (female)	1,219 (61.7)	496 (68)	723 (58)	<0.001	942 (61.6)	277 (62)	0.60	192 (59)	1,027 (62)	
Current use of CGM	881 (44.6)	359 (49.3)	522 (41.8)	<0.001	705 (46.1)	176 (39.4)	0.011	116 (35.9)	765 (46.3)	<0.001
Daily frequency of checking glucose*	4.72 ± 2.4	5.01 ± 2.6	4.61 ± 2.5	0.001	4.71 ± 2.5	4.93 ± 2.6	0.112	4.96 ± 2.6	4.72 ± 2.5	0.136
Current use of insulin pump	1,374 (69.6)	524 (72)	850 (68.1)	0.052	1,085 (70.9)	289 (64.9)	0.019	196 (60.7)	1,178 (71.2)	0.001
Any SH (≥1 SH) in past 12 months	447 (22.6)	239 (32.8)	208 (16.7)	<0.001	0%	100%		323 (100)	124 (7.5)	
RSH (≥2 SH) in past 12 months	323 (16.3)	181 (24.9)	142 (11.4)	<0.001	0%	72.3		100%		
IAH (Gold score ≥4)	728 (36.8)	100%	0%		489 (32)	239 (53.5)	<0.001	181 (56.0)	547 (33.1)	

Data are mean ± SD or *n* (%) unless stated otherwise. *Participants were asked, "On average, how many times per day are you checking your blood sugar with a blood glucose meter?"

hypoglycemia concerns less (U = 414,971.00; z = −3.240; P = 0.001) but prioritized avoidance of hyperglycemia more (U = 418,156.50; z = −3.008; P = 0.003), with no significant difference in scores for Asymptomatic Hypoglycemia Normalized (P = 0.554).

Compared with those reporting no SH, those who had experienced any episodes of SH in the past year prioritized avoidance of hyperglycemia (U = 313,008.0; z = −2.753; P = 0.006) and normalized asymptomatic hypoglycemia more (U = 319,715.50; z = −2.148; P = 0.032), with a nonsignificant trend toward lower scores for hypoglycemia concerns minimized (U = 290,058.0; z = −1.627; P = 0.104).

Those with RSH normalized asymptomatic hypoglycemia more (U = 238,314.000; z = −3.148; P = 0.002) than those without RSH. Trends toward prioritizing avoidance of hyperglycemia more (U = 249,437.00; z = −1.903; P = 0.057) and minimizing hypoglycemia concerns less (U = 215,672.00; z = −1.486; P = 0.137) did not achieve statistical significance.

Those with RSH and IAH normalized asymptomatic hypoglycemia more than those with IAH but no RSH (U = 238,314.000; z = −3.148; P = 0.02), with nonsignificant trends toward higher scores for avoidance of hyperglycemia prioritized (U = 249,437.00; z = −1.903; P = 0.057) and lower scores for hypoglycemia concerns minimized (U = 252,116.500; z = −1.619; P = 0.105).

Sixty-five percent of participants with IAH responded to questions about the extent to which they believed it was possible to regain awareness, concern about lack of awareness, and motivation to regain awareness. Those with RSH were more concerned about having IAH (U = 16,853; z = −5.264; $P \leq$ 0.001) and more motivated to regain awareness (warning signs) (U = 18,222.0; z = −4.250; P = < 0.001) compared with those without RSH, but there was no significant difference in scores for how strongly participants believed they could regain awareness (U = 216,664.5; z = −1.652; P = 0.099. Eleven percent of those with IAH and RSH rated their concern about lack of awareness as "not at all" or "slightly."

Examining individual A2A items (Table 3), those with IAH had higher scores for item 14 than those with intact awareness (P < 0.001), indicating they were more

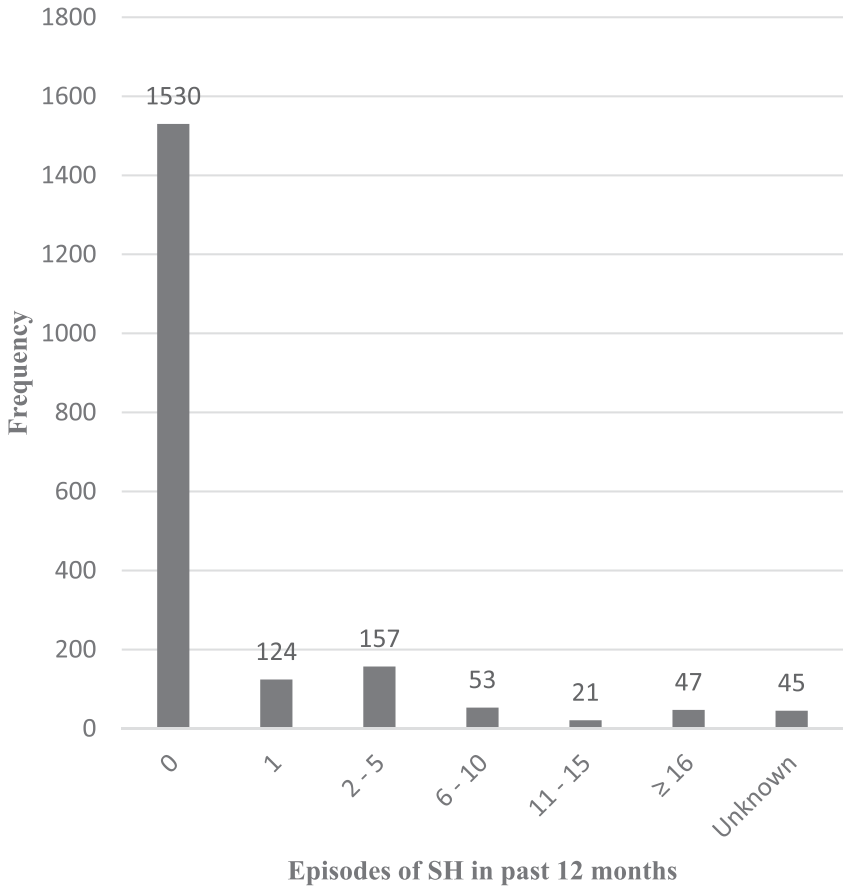

Figure 1—Distribution of self-reported episodes of SH in the preceding 12 months.

likely to believe that hypoglycemia does not affect their ability to function. They had lower scores for items 9 and 13 (questions included to check the accuracy of individuals' perceptions of their own risk) than those with intact awareness (item 9, $P < 0.001$; item 13, $P = 0.011$), indicating that they believed the statements were less true for them. There was no difference in responses to these questions by frequency of SH.

Repeating the analyses without item 11, with its factor loading of just under 0.3 on Minimizing Hypoglycemia Concerns, did not materially affect the results. For those with IAH versus intact awareness, the data were $U = 423{,}883.5$; $z = -2.554$; and $P = 0.011$, although for those reporting any SH versus none, the trend to significance became significant ($U = 306{,}093.00$; $z = -3.434$; $P = 0.001$), as did the difference in this factor for those with RSH versus no RSH ($U = 237{,}227.50$; $z = -3.238$; $P = 0.001$).

Across the whole cohort, participants with a university degree had higher scores for Hyperglycemia Avoidance Prioritized (mean rank 1,021.5 vs. 923.2; $z = -3.681$; $P < 0.001$) but did not differ from those without a degree on the other factors ($P = 0.43$ and 0.41). For HbA_{1c}, there was a small positive correlation with Asymptomatic Hypoglycemia Normalized ($r_s = 0.145$; $P < 0.001$) and a small negative correlation with Hypoglycemia Concerns Minimized ($r_s = -0.067$; $P = 0.011$) and no relationship with Hyperglycemia Avoidance Prioritized ($r_s = 0.013$; $P = 0.62$).

CONCLUSIONS

We have described the frequency of SH and the prevalence of IAH in a population of U.S. adults receiving specialist care for T1D and, for the first time, described the prevalence and distribution of health beliefs about hypoglycemia and hyperglycemia that may be relevant to individual risk for SH in this population.

In this U.S. sample, we demonstrated the structure and internal consistency reliability of a brief, novel questionnaire comprising 12 items about health beliefs. We identified three groupings of beliefs originally described in a U.K. qualitative study of adults with T1D and IAH (22), which may present a barrier to avoiding hypoglycemia. We accepted eigenvalues of >1 and α levels of >0.4 in the factor analysis, as is accepted practice (28,30). Variables that loaded strongly onto more than one factor were assigned to the factor with highest loadings. We did include one item with a loading of 0.297. Although this factor loading is low, we retained the item, as its inclusion gives greater face validity to the subscale and a balance of four items per subscale. Each grouping contained items of related theme, allowing us to label the groups.

One group of beliefs described a tendency to normalize asymptomatic hypoglycemia, illustrated by item 6. A second group described a tendency to minimize concern about hypoglycemia, exemplified by item 18, and a willingness to depend on others, with item 11. The third group described prioritizing avoiding hyperglycemia over risk of hypoglycemia, characterized by item 16, as well as acknowledgment of knowingly using more insulin than needed (item 19). The present analysis shows similarities to, and differences from, an exploratory U.K. analysis of the A2A (Supplementary Table 1). Each grouping shares at least two items across the two analyses, with three of four items concordant for factor C, Hyperglycemia Avoidance Prioritized, and two of the most strongly loading items concordant for each of factors A and B, Asymptomatic Hypoglycemia Normalized and Hypoglycemia Concerns Minimized. It is important to consider the differences. The U.K. population was much smaller ($N = 238$ vs. $N = 1{,}977$), was enhanced for participants with IAH (51.5%), and had much lower use of CGM (5.0% vs. 44.6%) and insulin pumps (30.7% vs. 69.6%). CGM provides the wearer with exogenous alerts to hypoglycemia and CGM and pump use reduce RSH. There is also a potential impact of cultural differences in how the items are interpreted, as the adjustments made to the language for the U.S. version of the questionnaire were minimal. However, we believe the U.S. structure to be stable, yielding groupings with plausible themes.

The large sample size is a strength of the study. At 32%, the response rate is within the range of rates reported in

Table 2—Structure and internal consistency reliability of the A2A questionnaire

	Forced three-factor solution*		
A2A item number: wording	Factor A: Asymptomatic Hypoglycemia Normalized	Factor B: Hypoglycemia Concerns Minimized	Factor C: Hyperglycemia Avoidance Prioritized
6: I don't need to treat low blood glucose, unless I feel symptoms	0.781		
15: Treating hypoglycemia when I don't have symptoms is a bother to me	0.727		
7: I'd rather live life to the fullest, than be too cautious about my diabetes	0.479		
10: There are no serious consequences to leaving mild hypoglycemia untreated	0.391		
18: I don't get easily worried about hypoglycemia		0.768	
17: I don't believe I'll have an SH episode in the future		0.752	
14: I can function okay with low (<55 mg/dL) blood glucose levels		0.416	
11: Someone will always be around to help me, if I have a low blood glucose episode		0.297	
16: I get frustrated and/or worried when I see high blood glucose readings			0.670
12: It's more important to avoid having high blood glucose than going low		0.336†	0.632
8: Good diabetes control is mainly about avoiding high blood glucose levels			0.600
19: Sometimes I know that I am giving myself more insulin than I really need			0.425
Eigenvalue	2.56	1.27	1.17
Percent variance explained	21.3	10.6	9.7
Cronbach α	0.51	0.46	0.47

*Factor loadings (principal components analysis): factor loadings <0.295 suppressed for clarity. †Not included in the scoring of the Hypoglycemia Concerns Minimized scale.

similar surveys (31) and higher than in some other annual questionnaires of T1D Exchange participants (32,33). There is a selection bias in that participants were enrolled in the T1D Exchange and willing to participate in its annual data collection. Educational attainment was higher than the general U.S. population, with greater numbers having at least high school qualifications (98.2% vs. 89.1%) or university qualifications (58.4% vs. 32.3%), using the most recent U.S. census data as comparator (34). Women and people of white, non-Hispanic ethnicity were more likely to complete the questionnaire, and the mean age and diabetes duration of respondents were 2 years higher than those of nonrespondents. The sex discrepancy was only 9% and the magnitude of difference in age and diabetes duration unlikely to be clinically important, although further studies will be needed to investigate the described cognitions in different ethnic groups. Importantly, the invitation to complete the questionnaire did not mention hypoglycemia or related cognitions, so we did not overrecruit people with problematic hypoglycemia, as confirmed by the prevalence of IAH.

Consistent with published literature, almost all RSH occurred in people with IAH (4,10,35). We defined both RSH and IAH as being either present or absent, based on conventional definitions of problematic hypoglycemia (≥2 SH episodes in 1 year [14] and IAH [Gold score ≥4] [10]). Rates of SH in this study were consistent with recent population-based studies (5) but higher than reported by a previous study of T1D Exchange clinic registry (23% vs. 11.8%) (36). The earlier report restricted the definition of SH to episodes resulting in seizure or loss of consciousness. We used the now widely accepted 2013 American Diabetes Association recommendation (37), "an event requiring assistance of another person to actively administer carbohydrates, glucagon, or take other corrective actions" (1). In a U.K.-Danish multicenter study, 36.7% of participants reported SH during the preceding year and 21.3% RSH (4). These higher rates are likely to be related to 57% having self-reported IAH in the U.K.-Danish sample compared with 37% in this study and may be influenced by the high use of CGM in our sample. Multiple regression analysis found IAH in the U.K.-Danish sample to have a relative risk for SH of 6.1 (4). The prevalence of IAH in our sample, although higher than the commonly quoted 20–24% (8), is comparable to the prevalence in a population of U.K. adults attending structured education in flexible insulin therapy (9) and may be more typical of people who either have long duration

Table 3—A2A scale scores, item response frequencies, and mean scores by awareness status and frequency of SH

	Awareness status										Frequency of hypoglycemia									
	IAH					Aware					RSH					No RSH				
A2A scale and item number: wording	0	1	2	3	Mean	0	1	2	3	Mean	0	1	2	3	Mean	0	1	2	3	Mean
	n (%)					*n* (%)					*n* (%)					*n* (%)				
Asymptomatic Hypoglycemia Normalized					1.45					1.45					1.51					1.44
6: I don't need to treat low blood glucose, unless I feel symptoms	545 (74.9)	95 (13)	61 (8.4)	27 (3.7)	1.41	921 (73.7)	166 (13.3)	93 (7.4)	69 (5.5)	1.45	214 (66.3)	51 (15.8)	35 (10.8)	23 (7.1)	1.59*	1,252 (75.7)	210 (12.7)	119 (7.2)	73 (4.4)	1.4*
15: Treating hypoglycemia when I don't have symptoms is a bother to me	610 (83.8)	74 (10.2)	32 (4.4)	12 (1.6)	1.24	1,055 (84.5)	128 (10.2)	47 (3.8)	19 (1.5)	1.22	249 (77.1)	43 (13.3)	20 (6.2)	11 (3.4)	1.36*	1,416 (85.6)	159 (9.6)	59 (3.6)	20 (1.2)	1.2*
7: I'd rather live life to the fullest, than be too cautious about my diabetes	345 (47.4)	245 (33.7)	98 (13.5)	40 (5.5)	1.77	556 (44.5)	441 (35.3)	182 (14.6)	70 (5.6)	1.81	147 (45.5)	93 (28.8)	48 (14.9)	35 (10.8)	1.91*	754 (45.6)	593 (35.9)	232 (14.0)	75 (4.5)	1.78*
10: There are no serious consequences to leaving mild hypoglycemia untreated	541 (74.3)	119 (16.3)	42 (5.8)	26 (3.6)	1.39	956 (76.5)	198 (15.9)	69 (5.5)	26 (2.1)	1.33	246 (76.2)	44 (13.6)	17 (5.3)	16 (5.0)	1.39	1,251 (75.6)	273 (16.5)	94 (5.7)	36 (2.2)	1.34
Hypoglycemia Concern Minimized					1.62					1.69					1.63					1.67
18: I don't get easily worried about hypoglycemia	314 (43.1)	266 (36.5)	117 (16.1)	31 (4.3)	1.81*	417 (33.4)	478 (38.3)	285 (22.8)	69 (5.5)	2.0*	155 (48)	107 (33.1)	45 (13.9)	16 (5.0)	1.76*	576 (34.8)	637 (38.5)	357 (21.6)	84 (5.1)	1.97*
17: I don't believe I'll have an SH episode in the future	498 (68.4)	152 (20.9)	57 (7.8)	21 (2.9)	1.45*	498 (68.4)	152 (20.9)	57 (7.8)	21 (2.9)	1.74*	230 (71.2)	60 (18.6)	23 (7.1)	10 (3.1)	1.42*	912 (55.1)	455 (27.5)	204 (12.3)	83 (5.0)	1.67*
14: I can function okay with low (<55 mg/dL) blood glucose levels	312 (42.9)	255 (35)	123 (16.9)	38 (5.2)	1.84*	725 (58)	352 (28.2)	137 (11)	35 (2.8)	1.59*	148 (45.8)	104 (32.2)	59 (18.3)	12 (3.7)	1.8*	889 (53.7)	503 (30.4)	201 (12.2)	61 (3.7)	1.66*
11: Someone will always be around to help me, if I have a low blood glucose episode	555 (76.2)	109 (15)	46 (6.3)	18 (2.5)	1.35*	885 (70.9)	222 (17.8)	102 (8.2)	40 (3.2)	1.44*	207 (64.1)	65 (20.1)	35 (10.8)	16 (5.0)	1.57*	1,233 (74.5)	266 (16.1)	113 (6.8)	42 (2.5)	1.37*

Continued on p. 1861

Table 3—Continued

	Awareness status										Frequency of hypoglycemia									
	IAH					Aware					RSH					No RSH				
A2A scale and item number: wording	0	1	2	3	Mean	0	1	2	3	Mean	0	1	2	3	Mean	0	1	2	3	Mean
	n (%)					*n* (%)					*n* (%)					*n* (%)				
Hyperglycemia Avoidance Prioritized					2.16					2.25					2.27					2.17
16: I get frustrated and/or worried when I see high blood glucose readings	33 (4.5)	97 (13.3)	223 (30.6)	375 (51.5)	3.29*	77 (6.2)	231 (18.5)	463 (37.1)	478 (38.3)	3.0*	25 (7.7)	55 (17)	92 (28.5)	151 (46.7)	3.14	85 (5.1)	273 (16.5)	594 (35.9)	702 (42.4)	3.16
12: It's more important to avoid having high blood glucose than going low	350 (48.1)	195 (26.8)	143 (19.6)	40 (5.5)	1.83	630 (50.4)	350 (28)	210 (16.8)	59 (4.7)	1.76	156 (48.3)	89 (27.6)	58 (18.0)	20 (6.2)	1.82	824 (49.6)	456 (27.6)	295 (17.8)	79 (4.8)	1.78
8: Good diabetes control is mainly about avoiding high blood glucose levels	218 (29.9)	202 (22.7)	227 (31.2)	81 (11.1)	2.23	351 (28.1)	398 (31.9)	355 (28.4)	145 (11.6)	2.24	87 (26.9)	90 (27.9)	91 (28.2)	55 (17.0)	2.35*	482 (29.1)	510 (30.8)	491 (29.7)	171 (10.3)	2.21*
19: Sometimes I know that I am giving myself more insulin than I really need	397 (54.5)	221 (30.4)	85 (11.7)	25 (3.4)	1.64	718 (57.5)	368 (29.5)	126 (10.1)	37 (3.0)	1.59	163 (50.5)	99 (30.7)	43 (13.3)	18 (5.6)	1.74*	952 (57.6)	490 (29.6)	168 (10.2)	44 (2.7)	1.58
Individual Perception of Risk					1.37					1.49					1.44					1.45
9: I don't need to worry about hypoglycemia because I don't get low blood glucose very often	551 (75.7)	138 (19)	32 (4.4)	7 (1.0)	1.31*	828 (66.3)	301 (24.1)	102 (8.2)	18 (1.4)	1.45*	232 (71.8)	56 (17.3)	23 (7.1)	12 (3.7)	1.43	1,147 (69.3)	383 (23.2)	111 (6.7)	13 (0.8)	1.39
13: I'm not too bothered about warning signs because SH is rare for me.	495 (68)	158 (21.7)	61 (8.4)	14 (1.9)	1.44*	770 (61.6)	336 (26.9)	102 (8.2)	41 (3.3)	1.53*	228 (70.6)	58 (18.0)	21 (6.5)	16 (5.0)	1.46	1,037 (62.7)	436 (26.4)	142 (8.6)	39 (2.4)	1.51

IAH is a Gold score ≥4, and RSH is ≥2 self-reported episodes of SH in the past year. All items scored on a Likert scale: 0 (not at all true) to 3 (very true). *Denote statistically significant results with $P < 0.05$ comparing IAH vs. Aware or RSH vs. No RSH.

of T1D and/or interest in receiving specialist care. In keeping with the literature, our participants with IAH had longer duration of diabetes, and were older, than those with intact awareness (10,35,36).

Also typical of other studies, those with RSH had longer duration of diabetes (4,36), although they were not older than those who had not experienced RSH. While this may appear to contrast with earlier data from the T1D Exchange clinic registry (6), the association between SH and age may be largely explained by the associated increase in diabetes duration (36). The latter study and ours, however, may have been underpowered to detect a weak relationship between age and RSH.

Our group with IAH had lower scores for minimizing hypoglycemia concerns than those with intact awareness of hypoglycemia, suggesting appropriate concern about hypoglycemia. This contrasts with lack of appropriate concern previously described for people with entrenched problematic hypoglycemia (22) but reflects the more diverse population of the current study and is compatible with the finding by Anderbro et al. (24) that two-thirds of people at high risk for SH have high concern, while one-third have low concern. Importantly, those with IAH scored higher than those with intact awareness in prioritizing avoidance of hyperglycemia. Although 11% did report inappropriately low scores, many individuals with IAH may have an accurate awareness about their higher level of risk for hypoglycemia, but heightened concern about avoiding hyperglycemia may override this and represent a barrier to engaging in behaviors to avoid hypoglycemia. This has been described previously among those with IAH (19), perpetuating the impaired awareness state. Those with IAH were also more likely to believe they could function normally during hypoglycemia than those with intact awareness. Meanwhile, the major difference in scores characterizing those with RSH, who also scored relatively low for minimizing hypoglycemia concerns, was in downplaying the potential impact of IAH, albeit with a trend toward enhanced prioritization of avoiding hyperglycemia. It may be this combination that puts them at greatest risk of continuing events. A similar pattern was seen in those with both IAH and RSH, and these people may contribute most to this pattern in the overall group with RSH. Although numbers are smaller for those with both IAH and RSH, reducing our power to detect significant differences, it is notable that this group comprised 9% of our total population, very similar to the 8% of the clinic population described by Anderbro et al. (24) as being at high risk for SH (one or more episodes of SH in the year) but with minimal concern about it.

Our study found a lower HbA_{1c} in the IAH group, a potential benefit not found in those with and without RSH—the group is smaller but the absence of a link is consistent with data from the study by Pedersen-Bjergaard et al. (4), which found that HbA_{1c} was not significantly associated with risk of SH. Indeed, we found higher mean HbA_{1c} in those with RSH versus those without. The absent or very weak correlations with the cognitive scores suggest that unhelpful cognitions about hypoglycemia do not contribute to the HbA_{1c} achieved and/or are not driven by it.

The use of insulin pumps and CGM was higher than that reported for the adult T1D Exchange population (38) in 2014 (50–60% for insulin pumps and 15.5% for CGM). The greater age of our participants (CGM use was 5.7% in those aged 18–26 vs. 21.4% in those aged $\geq$26 years in the earlier study), the ongoing trend toward greater technology uptake, and the finding that those willing to complete an online survey may be more likely to embrace technology to manage their diabetes may contribute to this discrepancy. Use of both pumps and CGM was higher in those with IAH, as would be expected, given that such technologies may be prescribed to address problematic hypoglycemia (14). Nevertheless, the higher use of CGM in those with current IAH is compatible with the failure of CGM to restore endogenous awareness of hypoglycemia, while providing technological awareness via alarms and alerts. Importantly, use of both pumps and CGM was lower in those with RSH compared with those with no RSH, despite RSH also being a recognized indication for their use. We cannot determine in this cross-sectional study to what extent the cognitions determine behaviors that lead to RSH or whether the hypoglycemia experience informs the cognitions.

Those using CGM were less likely to have had RSH in the past year (13.2% vs. 18.9%; $P = 0.001$), also consistent with a protective effect of CGM against RSH (18,39). Our data are also compatible with clinical experience that in general CGM does not restore awareness, although Clarke scores for awareness may improve as SH frequency is reduced (39).

A limitation of our study lies in the demography of our participants. We have already commented on the possibility that people from different cultural backgrounds may interpret the wording of the items in slightly different ways, and our study population was of predominantly non-Hispanic white ethnicity with high educational status. We acknowledge that further studies of the cognitions and the performance of this particular questionnaire need to be undertaken in other ethnic groups. Furthermore, given that the three factors in our brief questionnaire explain 41.6% of the cumulative variance (U.S. data; U.K., 44.7%) and the modest achieved internal consistency, further research to generate additional items and examine how their psychometric properties perform is now indicated. Finally, it is noteworthy that participants with a university degree had higher scores for Hyperglycemia Avoidance Prioritized than those without, and the impact of general education level should be further explored in future research.

In conclusion, this study expands upon earlier qualitative data, suggesting, for the first time in a large sample, that specific health beliefs about hypo- and hyperglycemia are associated with the development and/or maintenance of IAH with RSH in adults with T1D. For the first time, this study addresses which of those beliefs, namely, a lack of concern about asymptomatic hypoglycemia in combination with a fear of hyperglycemia, may be markers of highest risk of RSH. These beliefs may underpin observations that people with the most problematic hypoglycemia may be the least able to use, or gain benefit from the use of, therapeutic technologies with the potential to reduce SH. The findings are consistent with psychological perspectives of beliefs and behaviors, IAH and SH forming a vicious circle maintaining problematic hypoglycemia. However, such beliefs are likely to be modifiable. A pilot study of a psychoeducational intervention

program, designed to address such beliefs, has shown improved self-management strategies and cognitive changes around hypoglycemia (40). Therefore, by addressing their underlying health beliefs, adults with T1D may be able to protect themselves from the risks of SH.

Acknowledgments. The authors thank consultant nurse Helen Rogers at King's College Hospital NHS Foundation Trust for the help and support in developing the U.S. version of the A2A questionnaire and Nicole Smith and the staff at the Jaeb Center for Health Research for including the additional questionnaires in the center's mailings. The authors also thank all of the participants in the T1D Exchange clinic registry who completed the additional questionnaires.

Funding. This study was funded by JDRF through research project grant 4-SRA-2017-266-M-N and the Leona M. and Harry B. Helmsley Charitable Trust through its support of the T1D Exchange clinic registry run by the Jaeb Center for Health Research. This study was also supported by the Collaboration for Leadership in Applied Health Research and Care South London of the National Institute for Health Research, U.K. J.S. is supported by core funding to the Australian Centre for Behavioural Research in Diabetes provided by Diabetes Victoria and Deakin University.

The opinions expressed in this paper are those of the authors and not of the National Institute for Health Research or other funders.

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

Author Contributions. A.J.C. conducted the analyses and drafted the manuscript. A.J.C., S.N.D., N.F., E.L.S., M.W., G.M., M.R.R., J.S., N.D.Z., and S.A.A. reviewed and contributed to the interpretation of the data and reviewed and approved the final version of the manuscript. A.J.C., E.L.S., N.D.Z., and S.A.A. designed this study in collaboration with S.N.D. and M.R.R. S.N.D. and M.W. collected and cleaned the data. J.S. advised on statistical analyses and data interpretation. S.A.A. is the guarantor of this work and, as such, had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Prior Presentation. Parts of this study were presented in poster form at the 53rd Annual Meeting of the European Association for the Study of Diabetes, Lisbon, Portugal, 11–15 September 2017, and at the 77th Scientific Sessions of the American Diabetes Association, San Diego, CA, 9–13 June 2017.

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