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PSYCHOSOCIAL ASPECTS (S JASER AND KK HOOD, SECTION EDITORS)

# Fear of Hypoglycemia in Children and Adolescents and Their Parents with Type 1 Diabetes

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**Abstract** Hypoglycemia is a frequent occurrence in children and adolescents with type 1 diabetes. A variety of efforts have been made to standardize the definition of hypoglycemia and to define one of its most significant psychosocial consequences—fear of hypoglycemia (FOH). In addition to documenting the experience of FOH in children and adolescents type 1 diabetes and their parents, studies have investigated the relations between FOH and glycemic control and diabetes technology use. This review provides a summary of the recent FOH literature as it applies to pediatric type 1 diabetes.

**Keywords** Anxiety · Assessment · Blood glucose levels · Intervention · Youth

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## Introduction

Hypoglycemia is one of the most common and acute complications of insulin therapy that can lead to uncomfortable counter-regulatory symptoms including headaches, shakiness, nervousness, sweating, irritability, confusion, sleepiness and fatigue, weakness, dizziness, and dangerous neuroglycopenia [1–4]. In the most extreme cases, seizures, loss of consciousness, and death may occur. For many individuals, acute complications including fear of hypoglycemia preclude them from optimal diabetes management.

The immediate discomfort caused by hypoglycemia, chance for further harm long term, and potential unpredictability of these episodes causes individuals with diabetes and their family members to develop symptoms of anxiety and concerns related to hypoglycemia. In some cases, this anxiety can be adaptive, leading to appropriate vigilance in glucose management [1–4]. However, in many individuals with diabetes and their families, significant levels of anxiety can lead to disruptions in daily activities (e.g., sleep), suboptimal diabetes management and glucose control, and impaired quality of life [5, 6]. Within the diabetes literature, the terms "fear of hypoglycemia (FOH)" and "hypoglycemia fear" have been coined to reference the more severe anxiety-like symptoms that individuals with diabetes and their families may display [5]. Moreover, this term subsumes worry about hypoglycemia and engagement in "hypoglycemic avoidance behaviors" including over-vigilant blood glucose monitoring, maintaining elevated blood glucose levels by intentionally withholding insulin, and/or the premature or overtreatment of hypoglycemic events [1, 3, 7].

Several reviews of the FOH literature have been conducted, with the last comprehensive review completed in 2007 [6] and a review of FOH specific to parents of young children in 2010 [7]. In addition, an updated review of FOH in adults with type 1 diabetes was recently published [8••]. Therefore, the overall

purpose of the current review is to summarize studies examining FOH in children and adolescents with type 1 diabetes and their parents that have been published in the last decade. We also provide an overview of hypoglycemia and its consequences, questionnaires used to assess FOH, interventions that are available to treat FOH, and the potential for technology to impact FOH.

## Definition of Hypoglycemia and its Consequences

Hypoglycemia has historically been defined as abnormally low blood glucose levels of <70 mg/dL (3.9 mmol/L). However, Bergenstal and colleagues [9••] recently proposed more refined categories of hypoglycemia and recommended standardizing glucose reporting by classifying hypoglycemia into three categories: (1) 61–70 mg/dL (3.4–3.9 mmol/L) is considered "low;" (2) 51–60 mg/dL (2.8–3.3 mmol/L) is "very low;" and (3) <50 mg/dL (2.8 mmol/L) is "dangerously low." These categories are consistent with the 2005 American Diabetes Association (ADA) Workgroup on Hypoglycemia [10] and the 2016 ADA Standards of Medical Care [11].

Episodes of severe hypoglycemia require assistance of another person to "actively administer carbohydrate, glucagon, or other resuscitative actions" [10], and the experience can be psychologically traumatic, not only to the individual with diabetes, but also to others who observe the episode and provide aid. Measurement of blood glucose at the time of symptoms of severe hypoglycemia is not necessary, and resolution of symptoms with administration of glucose or other resuscitative action is sufficient to diagnose severe hypoglycemia [10]. Recurrent hypoglycemia occurs when hypoglycemia occurs frequently (e.g., 2–4+ episodes per week) [12], which can result in hypoglycemia unawareness or a reduction in the blood glucose level threshold required to induce the counter-regulatory hormone response to hypoglycemia [13–15].

Hypoglycemia unawareness is worrisome as it may lead to a delay in or loss of the initial hypoglycemia warning signals prior to more severe presentations, such as confusion, seizure, or loss of consciousness. Hypoglycemia unawareness occurs in about 25 % of individuals with type 1 diabetes [16] and leads to a sixfold increase of severe hypoglycemia [17]. In fact, the Diabetes Control and Complications Trial demonstrated that 32 % of severe hypoglycemic episodes involved seizure or coma [18]. Despite some earlier concern, there does not appear to be negative long-term consequences of repeated hypoglycemia on brain functioning [19]. In fact, some studies suggest general repeated hypoglycemia is potentially beneficial because the brain responds to it by improving cognitive functioning and increasing its fuel supply during times of euglycemia [19]. However, there is clinical concern regarding the interaction of hypoglycemia history and acute glycemic changes in the patient's ability to cope with immediate situations [19].

## Frequency of and Risk Factors Associated with Severe Hypoglycemia

It is difficult to estimate the rates of severe hypoglycemic episodes because of differences in definitions and reporting metrics [20]; however, as many as 35 % of individuals with type 1 diabetes have reported experiencing 2-4 or more episodes of hypoglycemia per week [12]. More recent pediatric data highlight the continued problem of severe hypoglycemia (defined by seizure/loss of consciousness) with rates ranging from 5 to 12 % [21, 22•]. Of particular concern is that a disproportionate number occur in a subset of youth; 79 % of severe hypoglycemic episodes occur in 14 % of children with type 1 diabetes [5, 23].

Historically, better glycemic control and intensive insulin therapy (i.e., ≥3 insulin injections per day or the use of an insulin pump) have been associated with increased episodes of severe hypoglycemia [12]. However, recent studies support the opposite—better glycemic control is no longer a strong predictor of severe hypoglycemia in pediatric type 1 diabetes [22•, 24•]. Other factors associated with increased risk for hypoglycemia include more frequent blood glucose monitoring (which may be both a cause and a consequence of FOH); longer diabetes duration; and female sex [24•]. In contrast, older age [24•] and insulin pump use [25] have been shown to decrease risk for severe hypoglycemia.

## Assessment of Fear of Hypoglycemia

To measure FOH, a number of questionnaires exist, including several translations [26, 27, 28•]. The oldest and most commonly used questionnaire is the Hypoglycemia Fear Survey (HFS), which was designed to measure worry related to hypoglycemia and hypoglycemia-avoidant behaviors in adults with type 1 diabetes [29]; however, clinical cutoffs do not exist which limits interpretability and use clinically. This 33-item questionnaire uses a Likert response format ranging from Never to Always. To score the HFS, items are summed to yield two subscale scores: the Behavior (HFS-B) and Worry (HFS-W) scores and a Total score. The HFS is psychometrically sound and has been widely used either in its entirety or just the Worry scale [29–31]. In addition, multiple adaptations of the HFS have been published to measure FOH in alternative patient groups and family members [5, 31–33]. The HFS was revised in 2011, yielding the HFS-II [34]. Like the original HFS, the HFS-II is designed for adults, uses a Likert format for item responses, and includes 33 items [34]. However, more than half of the items

for the HFS-II have been updated to reflect modern diabetes therapy as well as to measure hypoglycemia risk and perceived hypoglycemia unawareness [34]. Results of a large study have demonstrated sound psychometric properties for the HFS-II, including good test-retest reliability and validity based on positive correlations between the HFS-II and other measures of distress as well as confirmatory factor analysis [34]. Notably, the authors strongly recommend administering the full 33 items of HFS-II as opposed to just the HFS-W, highlighting the differences in how the HFS-B and the HFS-W relate to quality of life as evidence that only the full measure truly captures one's affective experience and reaction to hypoglycemia [34].

Based on the HFS, two measures of FOH have been developed for parents to complete [29, 32, 35], The HFS for Parents (HFS-P) is a 25-item questionnaire designed for parents of children (>8 years old) and adolescents [33]. The HFS for Parents of Young Children (HFS-PYC) is a 26-item questionnaire designed for parents of children less than 8 years old [31, 32]. Like the HFS, both the HFS-P and the HFS-PYC yield subscale scores that reflect parental worry about hypoglycemia and the behaviors parents may engage in to avoid a hypoglycemic episode for their child. For the HFS-P, the Behavior subscale has 10 items and the Worry subscale has 15 items [33]. For the HFS-PYC, there are also 10 items on the Behavior subscale, but the Worry subscale has 16 items, adding the item, "My child having a low blood sugar while I am driving" [31, 32]. Both the HFS-P and the HFS-PYC have demonstrated good psychometrics [31]. Interestingly, the available research suggests that parental HFS scores may be higher than scores for adults with type 1 diabetes, although there was little difference in scores for parents of very young children and parents of older children and adolescents [32, 33].

The HFS has also been modified for use in youth 6–18 years old [33]. The Children's Hypoglycemia Fear Survey (HFS-C) retains the two subscale structure of the HFS and has 25 items: 10 items on the Behavior subscale and 15 items on the Worry subscale [36]. However, a recent analysis revealed additional subscales of the HFS-C—two subscales within Worry, Helplessness and Social Consequences and two subscales within Behavior, Maintain High Blood Glucose and Avoidance [37••]. Several studies have used the HFS-C and demonstrated adequate internal consistency for the measure [36, 38]. In addition, one study, set at a diabetes camp, reported that the HFS-C has good test-retest reliability [36]. Data evaluating the validity of the HFS-C are limited, but at least one study has shown a positive correlation between the Worry subscale and a measure of general anxiety, providing some evidence of convergent validity [38].

The Children's Hypoglycemia Index (CHI) was developed separately from the HFS but also assesses FOH [39]. The CHI was designed to measure three areas of FOH: children's general fear related to hypoglycemia and its consequences (General), children's fear related to having a hypoglycemic episode within specific settings (Situation), and the behaviors children might engage in to avoid hypoglycemia (Behavior). The CHI includes 25 items scored on a Likert scale ranging from Not Afraid to Extremely Afraid or Never to All the Time, depending on the item. The CHI yields subscale scores for each of the three areas of FOH (i.e., General, Situation, Behavior) as well as a total score. The CHI was piloted in 109 children with type 1 diabetes, ages 8–16 years old (87 % Caucasian, 61 % boys), and results demonstrated good internal consistency and test-retest reliability. In factor analysis, the CHI retained its three-factor structure and convergent validity was demonstrated based on positive correlations between the CHI, the HFS-C, and a measure of general anxiety. Although the CHI has not been as widely used as the HFS-C, the addition of the Situation subscale may be particularly relevant for some youth whose fear may be partially situation-specific. However, more research and testing of the psychometrics of the CHI are needed [39].

## Factors Associated with Fear of Hypoglycemia

An increasing number of studies have focused on assessing FOH, although most studies focus on parents, or adolescents and their parents, with very few studies examining FOH in younger children. Table 1 provides descriptions of the samples and findings from studies that have been published on FOH in the last decade. As expected, the most common predictor of FOH across almost all studies was parent report of their children experiencing severe hypoglycemic episodes [27, 31, 34, 37••, 40, 41]. However, no study has verified this by examining FOH in relation to objectively downloaded glucometer or insulin pump data.

In contrast, studies have examined the association between FOH and glycemic control in children. Interestingly, the majority of these studies demonstrate no association. However, a small number of studies have found a positive association between parents' FOH and children's glycemic control [32, 40, 42]. Specifically, Haugstvedt and colleagues [42] found that higher parent scores on the HFS Worry scale were associated with higher child A1C values, whereas Patton et al. found a positive association between parents' HFS Behavior scores and young children's A1C values. Regarding youth scores, Johnson and colleagues [40] found that higher child/adolescent total scores on the HFS were associated with higher A1C values. Finally, in the most recent study, Freckleton and colleagues [41] found that higher parent HFS Behavior scores were associated with self-reported diary records of higher daily blood glucose levels, although no association with children's A1C was reported.

**Table 1** Studies examining FOH: characteristics and results

| Source | Sample size | Age range of child | HFS version | HFS M ± SD^ | Results |
|---|---|---|---|---|---|
| Gonder-Frederick, Fisher, et al. (2006) [38] | 29 adolescent-parent dyads | 12–17 | HFS-P (25 items)<br>HFS-C (25 items) | Parent $T = 66.44 \pm 14.47$<br>Adolescent $T = 65.24 \pm 13.24$<br>Parent $W = 36.9 \pm 11.62$<br>Adolescent $W = 33.87 \pm 11.61$<br>Parent $B = 29.55 \pm 6.01$<br>Adolescent $B = 31.36 \pm 7.38$ | Adolescent FOH and parent FOH not correlated. For adolescents, higher trait anxiety and more frequent episodes of severe hypoglycemia predicted higher FOH; for parents, whether adolescent carried rescue carbs predicted lower parent FOH. |
| Patton, Dolan, Henry, et al. (2007) [32] | 24 parents | 2–8 | HFS-PYC | $T = 81 \pm 14.1$<br>$W = 44.3 \pm 11.1$<br>$B = 33.7 \pm 5.3$ | HFS-PYC includes an added question about fear related to their child having a low blood glucose while the parent is driving. Lower SES was associated with higher parent Total and Worry scores. HFS-PYC Behavior scores positively correlated with A1C. |
| Patton, Dolan, et al. (2008) [31] | 81 mothers, 64 fathers | 2–8 | HFS-PYC | Mother $T = 75 \pm 17.2$<br>Mother $W = 42 \pm 13.5$<br>Mother $B = 33 \pm 6.2$<br>Father $T = 66.5 \pm 18$<br>Father $W = 38 \pm 13.4$<br>Father $B = 29 \pm 6.5$ | HFS-P adapted for use with young children to include age appropriate activities. Good internal consistency and test-retest reliability; mothers had higher scores on HFS-PYC Total and Behavior subscales than fathers. Mothers' HFS-PYC Worry significantly correlated with frequency of hypoglycemic events. FOH not related to A1C. |
| Haugstvedt, Wentzel-Larsen, et al. (2010) [42] | 103 Norwegian mothers and 97 fathers | 1–15 | HFS-P (25 items; translated into Norwegian) | Mother $T = 70.9 \pm 12.6$<br>Mother $W = 37.7 \pm 8.9$<br>Mother $B = 33.2 \pm 6.2$<br>Father $T = 66.1 \pm 11.7$<br>Father $W = 36 \pm 8.5$<br>Father $B = 30.1 \pm 6$ | Higher HFS-P Worry related to higher A1C and higher frequency of hypoglycemic events. HFS-P Behavior scores higher in parents of children on MDI than pump. Mothers' scores on the HFS-P Worry and Behavior were higher than fathers' scores. |
| JDRF CGM Study Group [53] | 228 children/adolescents and 223 parents | <18 | HFS Worry | Child $W = 25.7 \pm 16.6$ (CGM)<br>Child $W = 25.9 \pm 14.9$ (BGM)<br>Parent $W = 41.5 \pm 16$ (CGM)<br>Parent $W = 42.2 \pm 19.8$ (BGM) | No differences in HFS Worry between CGM group and BGM group (finger stick). Parents reported more worry than children. |
| Gonder-Frederick, Nyer, et al. (2011) [5] | 259 children/adolescents; 250 parents | 6–18; age groups: 6–8, 9–11, 12–18 | HFS-P and HFS-C+ | Child $T = 1.52 \pm 0.57$***<br>Child $W = 1.10 \pm 0.73$<br>Child $B = 2.17 \pm 0.63$<br>Parent $T = 1.90 \pm 0.57$<br>Parent $W = 1.75 \pm 0.63$<br>Parent $B = 2.38 \pm 0.60$ | Demonstrated reliability and validity of the HFS-P and HFS-C in younger children and across age groups. HFS-C Worry scores in 9–11-year-olds equalled 12–18-year-olds but were higher than 6–8-year-olds. HFS-P Behavior scores (for children 6–8 and 9–11) were higher than parents' scores of children 12–18. Child and parent FOH significantly correlated across all age groups. FOH not related to A1C. |
| Patton, Dolan, et al. (2011) [55] | 39 parents | 2–7 | HFS-PYC (26 items) | $T = 78.6 \pm 18.4$ | More frequent parental stress and more difficulty with parenting stress were associated with higher FOH. |
| Markowitz, Pratt, et al. [56] | 28 children/adolescents and their parents | 8–17 | HFS (23 items) | Child $T = 15.8 \pm 12.2$ (BGM)<br>Child $T = 17.9 \pm 14.1$ (CGM)<br>Parent $T = 23.1 \pm 17.2$ (BGM)<br>Parent $T = 18.8 \pm 20$ (CGM) | Parents reported higher FOH than their children. No differences in FOH between CGM and BGM groups. |
| Freckleton, Sharpe, and Mullan (2013) [41] | 71 mothers | 2–12 | HFS-P+ | – | HFS-P Behavior and Worry not associated with A1C. Higher scores on HFS-P Behavior were associated with higher daily blood glucose levels. |
| Johnson, Cooper, et al. (2013) [40] | 196 Australian children/adolescents; 325 parents | 2–18 | HFS-P and HFS-C+ | – | Higher FOH associated with lower diabetes-specific QOL in both children/adolescents and parents. Children/adolescents with higher FOH had higher A1Cs. FOH not |

**Table 1** (continued)

| Source | Sample size | Age range of child | HFS version | HFS M ± SD^ | Results |
|---|---|---|---|---|---|
| | | | | | related to A1C for parents. Parents with higher FOH associated with more episodes of severe hypoglycemia, but not for children/adolescents. |
| Barnard, Wysocki, et al. (2014) [50] | 16 adolescents and parents | 12–18 | HFS* (23 items) | Parent $T = 65.7 \pm 1.4$<br>Adolescent $T = 60.1 \pm 1.2$ | Artificial pancreas study. Adolescent scores declined throughout the course of the study, whereas parent scores increased. |
| Shepard, Vajda, et al. (2014) [37] | 259 children/adolescents; 250 parents | 6–18 | HFS-P and HFS-C (25 items) | Same sample as Gonder-Frederick, Nyer, et al. (2011) | Factor analyses revealed two subscales within Worry: Helplessness and Social Consequences and two subscales within Behavior: Maintain High Blood Glucose and Avoidance. High HFS-C scores on Maintain High Blood Glucose were associated with higher mean blood glucose levels and more hyperglycemic readings, but not A1C. Higher HFS-C Avoidance scores with fewer hypoglycemic episodes. |
| Al Hayek, Robert, et al. (2015) [26] | 187 Saudi Arabian adolescents | 13–18 | HFS-C (32 items) | $W = 2.16 \pm 1.08$ (13–15 years)<br>$W = 2.49 \pm 0.70$ (16–18 years)<br>$B = 1.96 \pm 0.73$ (13–15 years)<br>$B = 2.55 \pm 0.63$ (16–18 years) | Females had higher scores on the HFS-C than males. Older age, MDI, longer type 1 diabetes duration, higher frequency of hypoglycemia, and hypoglycemia generally and in front of friends were associated with higher HFS-C scores. |
| Amiri, Vafa, and Gonder-Frederick (2015) [27] | 61 Iranian children | 6–12 | HFS-C (32 items) | $T = 55.9 \pm 17.9$ (age ≤ 9)<br>$T = 38.2 \pm 16.4$ (age ≥ 10)<br>$W = 31.1 \pm 14.7$ (age ≤ 9)<br>$W = 16.9 \pm 11.4$ (age ≥ 10)<br>$B = 24.8 \pm 7.7$ (age ≤ 9)<br>$B = 21.4 \pm 7.5$ (age ≥ 10) | No relationship between FOH and A1C. |
| Haugstvedt, Wentzel-Larsen, et al. (2015) [28•] | 176 parents | 6–15 | HFS-P (25 items; translated into Norwegian) | – | Factor analysis revealed support for the HFS-P Worry subscale. However, support for the Behavior subscale was weak. Further refinement of the scale was recommended. |
| Ziegler, Liberman, et al. (2015) [51] | 40 adolescents | 10–18 | HFS-C** | $T = 1.33 \pm 0.41$****<br>$W = 1.04 \pm 0.53$<br>$B = 1.78 \pm 0.49$ | It appears that the HFS scores were collapsed between all participants, 19 of whom were >18 years. FOH was low at baseline; however, HFS Worry decreased after 4 nights of using the artificial pancreas system. |

Note. Some versions of the HFS have been modified by adding and/or deleting items.

*JDRF CGM* Juvenile Diabetes Research Foundation Continuous Glucose Monitoring, *BGM* Blood Glucose Monitoring, *HFS* Hypoglycemia Fear Survey, *HFS-C* Hypoglycemic Fear Survey-Child, *HFS-P* Hypoglycemic Fear Survey-Parents, *HFS-PYC* Hypoglycemic Fear Survey-Parents of Young Children, *MDI* Multiple Daily Injections, *T* Total score, *W* Worry score, *B* Behavior score

^For longitudinal studies, only baseline scores are reported

+Number of items not specified

*This study cited the adult version of the HFS; thus, it is assumed that the adult and not the child version was used

**Not clear if HFS was translated or administered in English

***Mean item scores: In this article, means and standard deviations are provided for each age group. For the purposes of this review, we collapsed the means and standard deviations across groups and averaged them

****Mean item scores

It is unclear why most studies fail to find a relationship between FOH and glycemic control given that it seems reasonable that engaging in specific hypoglycemia-avoidant behaviors (e.g., maintaining elevated blood glucose levels by intentionally withholding insulin and/or the premature or overtreatment of hypoglycemic events) would likely lead to elevated daily blood glucose levels and ultimately suboptimal glycemic control. It may be that extreme glycemic variability plays a significant role in the onset and maintenance of FOH. Nevertheless, the apparent lack of association between FOH and glycemic control in most studies may provide evidence of the number of different factors that contribute to children's glycemic control in addition to parent and child behavior. Future studies should investigate FOH in the context of blood glucose ranges as it may be that severity of FOH varies based on time spent in different ranges.

## Behavioral Interventions to Reduce Fear of Hypoglycemia

Although FOH has been extensively documented and studied in type 1 diabetes, much of this research has focused on understanding the symptoms associated with FOH and its implications for clinical care, describing rates, and relating it to health outcomes and other patient perceptions and experiences. Far less attention has focused on behavioral interventions aimed directly at reducing FOH, [6] and existing studies have focused solely on adults. No studies have focused on providing intervention to children and adolescents with type 1 diabetes and/or their parents to reduce FOH; therefore, the literature described next applies to adults, but the techniques certainly could be used with children and adolescents with type 1 diabetes and their parents.

There are specific interventions such as cognitive behavioral therapy (CBT) that have been shown to be effective in the treatment of depression and improving glycemic control, but there is limited research targeting FOH or other anxiety disorders in diabetes directly [43]. Only one study has specifically used CBT to reduce anxiety in diabetes, which was a case study [44]. Boyle and colleagues applied active ingredients of CBT for panic disorder (e.g., relaxation training, reframing catastrophic thinking, exposure to fears) with a patient who feared that hypoglycemia would lead to loss of behavioral control [44]. As a result, the patient experienced significant improvements in anxiety, depression, FOH, and self-care behaviors [44].

CBT can also be delivered in group format to improve glycemic control and reduce hypoglycemia-associated anxiety [45]. Amsberg and colleagues developed an 8-week group CBT program with weekly 2-h group sessions and 1-h individual session during week 7 conducted by a trained nurse specialist and psychologist. They were successful at improving glycemic control in the CBT group but simultaneously saw an increase in hypoglycemic episodes. Only behaviors to avoid FOH decreased in the CBT group without a significant change in worry [45].

Other interventions that showed a reduction in FOH are not behavioral intervention studies, but are focused on providing medical intervention or psychoeducation. For example, after 24 weeks of using insulin glargine according to defined algorithms, significant reductions in FOH across Worry and Behavior scales as well as improvements in general anxiety and depression were experienced by adults with type 1 and type 2 diabetes [46]. Other efforts have focused on providing training to better understand the symptoms of low and high blood glucoses in order to avoid extremes in glucose using Blood Glucose Awareness Training (BGAT), a psychoeducational programmatic intervention developed to improve one's ability to detect and interpret blood glucose levels. The underlying mechanism thought to mediate the relationship between BGAT and reducing FOH is that it may reduce the sense of loss of control or uncertainty associated with hypoglycemic episodes and increase confidence in recognizing and anticipating hypoglycemia through a better understanding of internal and external cues [47]. Specifically, BGAT aims to increase the accuracy of recognizing internal (e.g., symptoms, mood changes, cognitive difficulties) and external (e.g., knowledge of insulin) blood glucose cues. Targeted skills include recognizing and avoiding low and high blood glucoses sooner, treating them more effectively and efficiently, and improving quality of life. Cox and colleagues demonstrated that BGAT resulted in a reduction of worry about hypoglycemia as well as improved recognition of cues, improved judgments, and a reduction in severe incidents of hyper and hypoglycemia [47]. Another educational intervention, HypoCOMPaSS, delivered both in group and individual formats, aims to reduce the frequency of hypoglycemic events and assist individuals with maintaining glucose control and recognizing specific situations with increased hypoglycemic risk. HypoCOMPaSS has been found to reduce FOH worry and behaviors and to improve glucose control [48]. Interestingly, there was no difference in outcomes based on insulin delivery (insulin pump vs. multiple daily injections) or monitoring blood glucose (finger sticks vs. continuous glucose monitoring) methods.

## Technology's Impact on Fear of Hypoglycemia

Several artificial pancreas, or closed-loop, systems are currently under development, which consist of a continuous glucose monitor, insulin pump, and smart device containing algorithms that control how much insulin a patient needs based on blood glucose level and carbohydrates. The artificial pancreas has the potential to significantly impact frequency and time spent in hypo- and hyperglycemia; however, it will not

likely completely eliminate FOH because it is plausible that not all individuals with type 1 diabetes will adopt its use. In addition, it is not known how the artificial pancreas will function in those with problematic hypoglycemia (i.e., episodes of severe hypoglycemia are unpredictable, unexplained, and unpreventable) [49]. We are aware of only two studies to date that have evaluated FOH in a pediatric artificial pancreas trial. Barnard and colleagues [50] administered the HFS (adult version) at three time points to adolescents and their parents. Adolescents' scores decreased across the study, whereas parents' scores increased; notably, significance tests were not reported. Ziegler and colleagues [51] administered the HFS-C to children and adolescents in their study, but they appear to have combined the scores with adults. Although there was a reduction in HFS Worry, it is not clear if this was primarily in the pediatric or adult samples or both. We expect that as more artificial pancreas trials are conducted in the coming years, the impact of this technology on FOH will be elucidated.

Other technologies also have the potential to reduce FOH. In a study examining patient experiences after switching to automated bolus calculators with insulin pump therapy, Barnard and colleagues found that after 4–12 weeks of using the calculator, approximately half of patients reported a reduction in their FOH and 75 % of patients reported increased confidence in the insulin dose calculation above and beyond manual bolus calculation [52]. In contrast, however, the impact of continuous glucose monitoring on FOH is not clear, as a recent study comparing its use with standard self-monitoring of blood glucose found that only adults using continuous glucose monitoring had significantly lower FOH overall and lower FOH Behavior, but no change to Worry in adults or children across 26 weeks [53]. It may also be that having immediate and constant data from devices causes an unintended consequence of increased anxiety in parents and children.

## Conclusions

A substantial amount of research has demonstrated that FOH is a serious clinical concern in children and adolescents with type 1 diabetes and their parents. The child, adult, and parent versions of the HFS have been well-validated, and it is the most commonly used questionnaire to assess FOH; however, its use is currently limited to research because of its lack of clinical cutoffs to inform diabetes care teams of the clinical meaning of scores. Efforts are currently underway to remedy this problem but only in individuals with type 2 diabetes [54]. Additional research is needed to establish clinical cutoffs in individuals with type 1 diabetes, so that the HFS may become more widely adopted in clinical settings. Overall, the clinical application of FOH interventions is extremely limited in pediatric type 1 diabetes. In adults, there is evidence to support that clinically delivered educational methods reduce FOH [47, 48], but CBT interventions to specifically target reductions in FOH show promise [45]. In addition, Vallis and colleagues proposed that interventions should include graduated exposure exercises to assist individuals with managing their anxiety and lowering their threshold for low blood glucoses, which is usually much higher than 70mg/dL [57]. Again, these interventions have only been used in research settings with adults, and they have not been disseminated clinically. Finally, although newer technologies hold the potential for more sophisticated ways of handling insulin administration and calculation, further research is needed to understand both increased burden and decreased anxiety and how they interplay.

**Compliance with Ethical Standards**

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

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Papers of particular interest, recently published, have been highlighted as:
- • Of importance
- •• Of major importance


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