Original article:

Correlates and outcomes of worries about hypoglycemia in family members of adults with diabetes: the second Diabetes Attitudes, Wishes and Needs (DAWN2) Study

Running title: Worry about hypoglycemia in family members

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**ABSTRACT**

**Objective:** We examined (a) the demographic and clinical correlates of worries about hypoglycemia in adult family members of adults with diabetes, and (b) the association of these worries with measures of diabetes support.

**Methods:** The second multinational Diabetes Attitudes, Wishes and Needs (DAWN2) study cross-sectionally surveyed 2,057 family members from 17 countries. Participants completed questions about demographics, diabetes, and psychosocial functioning, including worry about overall and nocturnal hypoglycemia. Analyses included hierarchical ordinal and linear regression.

**Results:** Eighty-five percent of family members (n=1,661) were at least occasionally very worried about the risk of hypoglycemic events overall. Correlates of worries about hypoglycemia included female gender, higher age and lower education in the family member, younger age of the person with diabetes and this person being a parent or another adult (versus spouse or partner), insulin or non-insulin injectable treatment, severe or non-severe hypoglycemia in the past 12 months, and family member recognition of hypoglycemia. Elevated worries about hypoglycemia had a significant independent association with increased odds of diabetes-related family arguments and family member frustration in providing helpful support (OR range 1.60-3.72). High levels of worries about hypoglycemia were associated with increased odds of attending diabetes-related health-care visits. Worries about hypoglycemia were not associated with family member involvement in diabetes care. Similar results were found for worries about nocturnal events.

**Conclusion:** Worries about hypoglycemia were common in family members and were associated with suboptimal diabetes support. This issue therefore deserves increased clinician attention.

**KEY WORDS:** diabetes, family, hypoglycemia, worry, support

**INTRODUCTION**

Hypoglycemia is an important side-effect of insulin therapy and, to a much lesser extent, sulfonylurea treatment [1, 2]; it constitutes a serious problem for both people with type 1 and type 2 diabetes and is a major limiting factor in achieving tight glycemic control. Apart from the person living with diabetes, hypoglycemia may also have a considerable impact on family members [3]. Previous studies have mainly focused on parents of children with type 1 diabetes, finding considerable parental fear of hypoglycemia, affecting both parental health and quality of life [4]. Less is known about worries about hypoglycemia among family members of adults with diabetes. In the second Diabetes Attitudes, Wishes and Needs (DAWN2) study, 61% of the 2,057 adult family members of adults with diabetes surveyed indicated that they mainly or fully agreed to be very worried about the risk of hypoglycemic events [5]. The global qualitative data from DAWN2 confirm that worries about hypoglycemic events play a very significant role for family members and cohabitants of people with diabetes world-wide [6]. A recent history of severe hypoglycemia has been associated with increased worries about hypoglycemia in spouses of adults with type 1 diabetes [7, 8], but research focusing on the correlates of worries about hypoglycemia in a diverse range of family members of adults with diabetes is limited. These worries are associated with negative implications for psychological outcomes of family members, such as quality of life, diabetes distress and diabetes burden [9]. A qualitative study among 14 partners of adults with type 1 diabetes described significant worry, stress and anxiety about hypoglycemia and frustration in trying to prevent or manage it [10]. Participants also indicated that the conflict, moodiness, and irritability often associated with hypoglycemia added to interpersonal challenges. Recent experience with severe hypoglycemia has been associated with more marital conflict about diabetes management [8]. This suggests that worries about hypoglycemia in family members could also influence the quantity and quality of diabetes support provided to the person with diabetes. The importance of family support for managing diabetes has recently been highlighted through qualitative data from the DAWN2 study [6].

The correlates and diabetes support outcomes of worry about hypoglycemia in family members have not been studied in a large, culturally diverse sample of family members of adults with diabetes. Therefore, the primary aims of the present study were to examine (a) the correlates of worries about hypoglycemia in family members of adults with diabetes, and (b) the association of worries about hypoglycemia in family members with several measures of diabetes support by the family member. As hypoglycemic events during sleep appear to be experienced as particularly disturbing [11], analyses were repeated for worries about nocturnal hypoglycemia.

**METHOD**

**Procedure and participants**

The second Diabetes Attitudes Wishes and Needs (DAWN2) study was designed as a cross-sectional questionnaire survey to examine the attitudes, wishes and needs of people with diabetes, family members and healthcare professionals in 17 countries across four continents: Algeria, Canada, China, Denmark, France, Germany, India, Italy, Japan, Mexico, The Netherlands, Poland, Russia, Spain, Turkey, United Kingdom and United States of America [12]. A detailed description of study design can be found elsewhere [5, 12]. In brief, the sample of family members included adults (≥ 18 years) who were not diagnosed with diabetes themselves, who were living in the same household with an adult with (non-gestational) diabetes diagnosed at least 12 months ago, and who were involved in their diabetes care. Depending on each country’s situation and in order to maximize comparability of samples, a hybrid methodology was used where potential participants were identified from a variety of sources, including online panels and databases, telephone lists, proprietary databases, lists from past research, patient association lists, and hospital and physician directories. In each country, the study was conducted in accordance with ethical requirements, following national, regional or local guidelines with respect to non-interventional research. As a minimum standard, guidelines of the International Chamber of Commerce/European Society for Opinion and Marketing Research, the Council of American Survey Research Organizations and Good Pharmacoepidemiology Practices were used [12]. All participants provided informed consent. The survey was completed predominantly online or by telephone interview, supplemented by face-to-face interviews in countries with low internet access. As worries about hypoglycemia can be present even if diabetes treatment does not include sulfonylurea or insulin, all participants were included in the present analysis (irrespective of diabetes treatment modality).

**Measurements**

An overview of measurements can be found in Table 1. With respect to the main measurements, worries about hypoglycemia and support were assessed with individual items from several questionnaires specifically developed for the DAWN2 study. Items were answered on a 4 or 5 point Likert scale, depending on the questionnaire from which they were taken.

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**Statistical analyses**

Hierarchical (blockwise) regression analysis was used for analysis of all outcomes. Successive blocks of variables were entered into the model in the following order: (1) demographics of the family member (sex, age, educational level, employment status, country of residence, relationship to the adult with diabetes, ≥2 adults with diabetes in household) and person with diabetes they were living with (sex, age); (2) diabetes treatment (use of insulin or non-insulin injectable diabetes medication); (3) frequency of severe and non-severe hypoglycemic events in previous 12 months; (4) hypoglycemia self-efficacy of the family member; (5) worries about hypoglycemia (for analyses of diabetes support/involvement). For categorical predictors with more than 5% (100) missing values (Table 2), separate “missing” categories were created and included in the model to retain as many participants as possible for the regression analysis. For variables with fewer missing values, cases with missing values were dropped from the analysis. Cases with missing values for each outcome were dropped from the analysis of that outcome.

The analysis of family member worry about hypoglycemia was repeated with worry about overall and nocturnal hypoglycemia as the dependent variables. For the subgroup of family members who reported that the person they lived with had experienced hypoglycemia (severe or non-severe) in the previous 12 months, we repeated these analyses with the addition of family member difficulties in recognizing hypoglycemia to the model. Analyses also examined the relations between family member worries about hypoglycemia (overall and nocturnal) and the potential outcomes: (1) diabetes-related family arguments, (2) family member attending of health care provider visits, (3) family member frustration in providing helpful support, and (4) family member involvement in diabetes care.

Analysis of single-item ordinal measures used ordinal regression. The assumption of proportional odds was checked for all model steps using the test of parallel lines and rejected for all models. However, this test often leads to an incorrect rejection of the proportional odds assumption when the number of independent variables is large, the sample size is large, or when a continuous independent variable is included in the model [13], which are all the case for the present analyses. Analysis of family member involvement in diabetes care used linear regression. All analyses were performed using SPSS Version 22 (IBM SPSS Statistics, New York). Although multiple analyses were performed, we maintained a *p*-value <0.05 to indicate statistical significance, given the exploratory nature of the study.

**RESULTS**

**Sample characteristics**

Characteristics of the total sample of family members (n=2,057) are displayed in Table 2. With respect to the statement “I am very worried about the risk of him/her having hypoglycemic (low blood sugar) events”, 85% (n=1,661) of family members experienced at least some worry about the risk of hypoglycemic events overall. A similar number was found for family member worry regarding nocturnal hypoglycemic events (n=1,620). With respect to diabetes support, 44% (n=867) of family members mainly or fully agreed that they argued about diabetes care with the person with diabetes they lived with, 54% (n=1,109) regularly attended visits to the health care professional regarding diabetes, and 37% (n=760) were somewhat or very frustrated that they did not know how best to help with diabetes care. Concerning family member involvement in diabetes care, the person with diabetes had slightly more responsibility than the family member in most cases.

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**Correlates of worries about overall and nocturnal hypoglycemia**

The left column of Table 3 displays the final model of the ordinal regression analysis examining the correlates of overall worries about hypoglycemia (27% explained variance). The odds of experiencing a higher level of overall worries about hypoglycemia was increased when the family member was female, older, and did not have college education, when the person with diabetes was younger, when they were a parent or other adult compared to a spouse or partner, when diabetes treatment included insulin or non-insulin injectable medication, and when family members reported that the person with diabetes had experienced one or multiple severe hypoglycemic events or occasional or frequent non-severe events in the previous 12 months. Notably, (a) the odds for non-severe hypoglycemia were higher than the odds for severe hypoglycemia; (b) family member hypoglycemia self-efficacy was not associated with overall worries about hypoglycemia; (c) the strength of the association between diabetes treatment and overall worries about hypoglycemia decreased when the frequency of hypoglycemic events was added to the model in step 3.

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Results for family member worries about nocturnal hypoglycemia (right column of Table 3) were comparable to the results for the analysis with overall worries about hypoglycemia, with a few exceptions. Working part time due to diabetes (versus working fulltime) and helping another adult with diabetes (versus helping a spouse or partner) were initially associated with worries about nocturnal hypoglycemia, but no longer significant as from model 3 and model 4, respectively. Female gender of the family member became a significant correlate of worries about nocturnal hypoglycemia as from model 2. Age and educational level of the family member were not associated with worries about nocturnal hypoglycemia in any of the model steps.

**The role of family member difficulties in recognizing hypoglycemia**

In the subgroup of family members who reported that the person they lived with had experienced hypoglycemia (severe or non-severe) in the previous 12 months and who completed the question about family member hypoglycemia recognition, we examined whether family member difficulties in recognizing hypoglycemia was associated with family member worries about hypoglycemia (results not shown in Table). For overall worries about hypoglycemia (n=1,455), addition of family member difficulties in recognizing hypoglycemia to the model with demographics, diabetes treatment, frequency of hypoglycemic events, and family member hypoglycemia self-efficacy increased explained variance from 20% to 22%. Compared to family members who always recognized hypoglycemia, the odds of experiencing higher levels of overall worries about hypoglycemia were decreased in family members who often (OR=0.59, 95% CI 0.41-0.84, *p*=0.004), sometimes (OR=0.48, 95% CI 0.34-0.69, *p*<0.001), rarely (OR=0.37, 95% CI 0.25-0.55, *p*<0.001) and never (OR=0.28, 95% CI 0.17-0.47, *p*<0.001) recognized hypoglycemia. For worry about nocturnal events (n=1,462), addition of family member difficulties in recognizing hypoglycemia increased explained variance from 20% to 21%. Compared to family members who always recognized hypoglycemia, the odds of experiencing higher levels of worries about nocturnal hypoglycemia were decreased in family members who often (OR=0.63, 95% CI 0.44-0.89, *p*=0.01), sometimes (OR=0.57, 95% CI 0.40-0.81, *p*=0.001), rarely (OR=0.42, 95% CI 0.29-0.62, *p*<0.001) and never (OR=0.33, 95% CI 0.20-0.54, *p*<0.001) recognized hypoglycemia.

**Association between worries about overall hypoglycemia and family member diabetes support**

Table 4 displays the final results of the ordinal regression analyses and linear regression analysis examining the association between overall worries about hypoglycemia in family members and the level of support they provided. For all measures of support except family member involvement in diabetes care (diabetes-related family arguments, attending health care provider visits, frustration in providing helpful support), addition of overall worries about hypoglycemia led to a significant model improvement. Compared to family members who fully disagreed with the statement “I am very worried about the risk of him/her having hypoglycemic (low blood sugar) events” (reference group), those who mainly disagreed, those who mainly agreed and those who fully agreed all showed increased odds of experiencing diabetes-related family arguments. Furthermore, family members who fully agreed with the worries about hypoglycemia statement had increased odds of attending health care professional diabetes visits. In addition, family members who mainly disagreed, mainly agreed and fully agreed with the worries about hypoglycemia statement all showed increased odds of experiencing frustration about not knowing how to help the person with diabetes they lived with. Concerning family member involvement in diabetes care, worries about hypoglycemia were not associated with the level of responsibility the family member had in the diabetes care of the person with whom they lived.

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**Association between worries about nocturnal hypoglycemia and family member diabetes support**

Addition of worry about nocturnal hypoglycemia to the model with demographic and clinical factors and family member hypoglycemia self-efficacy led to a significant overall model improvement for diabetes-related family arguments, attending health care provider visits, frustration in providing helpful support, and family member involvement in diabetes care (results not shown in Table). Results for the association between worries about nocturnal hypoglycemia and family member diabetes support were similar to those for worries about overall hypoglycemia. However, both family members who fully and mainly agreed with the statement about worries about nocturnal hypoglycemia had increased odds of attending visits to health care professionals regarding diabetes.

**DISCUSSION**

**Key findings**

In this large and culturally diverse multinational sample of 2,057 family members of adults with diabetes, 85% were at least occasionally very worried about the risk of hypoglycemic events overall and 83% about the risk of nocturnal hypoglycemia. Overall worries about hypoglycemia in family members were associated with female gender, higher age and lower education in the family member, younger age of the person with diabetes, the person with diabetes not being a spouse or partner, insulin or non-insulin injectable treatment, severe or non-severe hypoglycemic events in the past 12 months, and recognition of hypoglycemic events by the family member. Family member hypoglycemia self-efficacy was not associated with family member worries about hypoglycemia. In turn, worries about hypoglycemia in family members were associated with a significant 1.5 to 4-fold increase in their odds of higher diabetes-related family arguments and frustration in providing helpful support to the person with diabetes with whom they lived. Family members with high levels of worries about hypoglycemia also had increased odds of attending diabetes-related visits to health care providers. Worries about hypoglycemia was not associated with family member involvement in diabetes care. Similar results were found for family member worry about nocturnal events.

**Interpretation of findings**

In line with previous findings among spouses and partners of adults with type 1 diabetes [7, 8, 10], we found that worries about hypoglycemia were common in a diverse group of family members of adults with diabetes. The correlates of worries about hypoglycemia in family members found in the present study are mostly comparable to the correlates of worries about hypoglycemia in people with diabetes [14, 15], with both the occurrence of severe and non-severe hypoglycemic events playing a major role (Hermanns et al., submitted). Similar to what has been reported in people with diabetes [15, 16], the occurrence rather than the frequency of severe hypoglycemia was associated with worries about hypoglycemia in family members. In addition to this, there are also data from parents of children with type 1 diabetes suggesting that fear of hypoglycemia is related more to the severity of hypoglycemia than the frequency [4]. Interestingly, in the present study the association of non-severe hypoglycemic events and worries about hypoglycemia in family members was stronger than the association for severe events, and increased when non-severe events were more frequent. Frequency of non-severe hypoglycemic events could be more important in determining worries about hypoglycemia than frequency of severe events, as the experience of many non-severe hypoglycemic events is a key risk factor for severe hypoglycemia. However, it is important to remember that the measurement metrics used in this study differ for the two types of events; it is likely that a single severe hypoglycemic event is more impactful than a single non-severe hypoglycemic event. Nevertheless, it is possible that the occurrence of non-severe hypoglycemic events triggers thoughts and fears in family members; for example, they may start thinking about future scenarios in which hypoglycemia leads to harm to the person with diabetes. Yet, this hypothesis requires further examination.

Unlike people with diabetes for whom it is suggested that hypoglycemia unawareness is associated with more worries about hypoglycemia [14], we found that family members who did not always recognize hypoglycemia in the person they lived with had lower levels of worries about hypoglycemia. These analyses were adjusted for the frequency of hypoglycemic events, among other variables. It could be that in family members who always recognize hypoglycemia, the family member frequently recognizes the occurrence of hypoglycemia before the person with diabetes themselves, leading to significant worries in the family member about hypoglycemia unawareness in the person with diabetes. Alternatively, if the person with diabetes has corrected the hypoglycemic event before the family member notices something is wrong, this might not induce worry in the family member. However, spouses of people with type 1 diabetes who had a history of severe hypoglycemia events appear predisposed to think about hypoglycemia. Nearly 20% would consider hypoglycemia when their partner did not show up at an appointed time and nearly 10% always considered the threat of severe hypoglycemia a family burden [7]; furthermore they also reported more hypoglycemia-related sleep disturbances [8]. Family member hypoglycemia self-efficacy was not associated with worries about hypoglycemia, in contrast to previous studies showing a negative relation between diabetes self-efficacy and worries about hypoglycemia in adults with diabetes [17] and parents of children with type 1 diabetes [18]. This could indicate that self-efficacy elements other than those focusing on the treatment of hypoglycemia are relevant, for example knowing what to do to prevent hypoglycemia.

Similar to a small study suggesting that spouses of people with type 1 diabetes with a recent history of severe hypoglycemia showed significantly more marital conflict about diabetes management [8], we found that worries about hypoglycemia were associated with diabetes-related family arguments and family member frustration in providing helpful support. Families who have not yet encountered any hypoglycemic events can also experience worry about hypoglycemia, potentially stemming from fear of events that might occur in future as diabetes progresses. Either driven by recent or remote severe or traumatic events or triggered by more general concerns about future events, worry about hypoglycemia risk could lead family members to take more control over diabetes management [19]. However, our results suggest that, while leading to increased family conflict over diabetes management, family member worries about hypoglycemia does not increase diabetes care responsibilities for the family member. When worries about hypoglycemia are high in family members, they appeared more likely to attend health care provider visits. This finding could not be explained by a lack of family member hypoglycemia self-efficacy, as higher self-efficacy was associated with higher odds of attending (suggesting that attendance at health care provider visits may have increased family members’ self-efficacy for dealing with hypoglycemia).

**Strengths and limitations**

The strengths of the study are the large, diverse sample of family members from 17 countries across the world and the inclusion of a range of demographic, clinical and psychological correlates. There are also several limitations. Worries about hypoglycemia was measured with a single purpose-designed item rather than a validated questionnaire such as the Hypoglycemia Fear Survey [20]. However, this item has been positively associated with diabetes distress and diabetes burden in family members of people with diabetes [9], providing some credence to its validity. Future research should examine specific concerns people may have about hypoglycemia, e.g. relating to cognitive difficulties, loss of consciousness, loss of control, embarrassment, negative social reactions, or long-term consequences for health [21, 22].

The present results are generalizable only to adult family members who did not have diabetes themselves and were involved in the diabetes care of an adult household member diagnosed at least a year ago. As all variables were determined through report by the family member, there is error in these measures. For example, family members may not have been aware of all hypoglycemic events that have occurred, especially non-severe events. On the other hand, previous studies have found that spouses and cohabitants tend to recall more episodes of severe hypoglycemia than people with diabetes themselves and that agreement between patients’ and cohabitants’ ratings are generally weak [23, 24]. This discrepancy may be due to different perceptions of what constitutes a hypoglycemic episode, temporary mental impairment during hypoglycemia, or deliberate “forgetting” of episodes due to embarrassment or other concerns [24]. In the DAWN2 study, diabetes type was based on self-report only. As report of diabetes type by family members may be inaccurate, we have therefore made a classification based on the use of insulin or non-insulin injectable medication. Whether the person with diabetes is using these types of medication as part of their treatment program will be more straightforward for family members to assess. Although this approach does not differentiate between the use of insulin versus non-insulin injectable medications, the number of people who use non-insulin injections but not insulin as reported by family members was small. While the present study examined worries about hypoglycemia overall and nocturnal hypoglycemia, no information was available about worry about events during the day. The number of participants per country (n≈120) did not allow the analyses to be undertaken for each individual country separately. While country was included in the analyses as a covariate, we cannot account for the potential impact of differences in health care systems across countries (e.g., access to education, therapy, health care providers) on worries about hypoglycemia. Finally, as the present analysis was based on a cross-sectional observational study, causal associations cannot be inferred.

**Clinical implications**

Worries about hypoglycemia in family members are a common and clinically relevant problem, associated with diabetes-related family arguments and family member frustration in providing helpful support. Therefore, better management of these worries in family members is needed. Our finding that family members who experienced high worries about hypoglycemia were more likely to attend diabetes-related health care visits suggests that regular care appointments are a good occasion to identify and address these issues. Family members could also be included in diabetes education. DAWN2 found that while only 23% of family members participated in any diabetes educational programs or activities, 72% of the respondents who participated in educational programs found them at least somewhat helpful [5]. Information provision about hypoglycemia prevention, recognition and treatment to patients as well as family members during diabetes education could potentially avoid or reduce worries in both groups.

Educational programs and behavioral interventions specifically aimed at reducing hypoglycemia and fear of hypoglycemia may also be of benefit. Blood glucose awareness training (BGAT) has been shown to reduce the frequency of episodes of severe hypoglycemia and to reduce fear of hypoglycemia in people with diabetes [25]. The DAFNE-HART (Hypoglycemia Awareness Restoration Training) pilot study also showed significant improvements in severe hypoglycemia, with a trend toward reduced worries about hypoglycemia [26]. Although it is known that relatives of people with diabetes are invited to participate in some courses aimed at preventing and managing hypoglycemic episodes [24], a formal assessment of changes in family member worries about hypoglycemia due to these interventions is currently lacking. Although family member hypoglycemia self-efficacy was not associated with worries about hypoglycemia in the present study, such interventions may not only increase feelings of control over hypoglycemia but also contribute to more constructive patient-relative coping with (the threat of) hypoglycemia. Our results suggest that it is important to target both the prevention of hypoglycemic events and the reduction of worries about hypoglycemia. In case of severely dysfunctional worries about hypoglycemia in family members, psychological counselling is warranted.

Additional support provided by diabetes technology should also be further explored. New technologies (e.g., insulin pump, continuous glucose monitor) may help to alleviate worry about hypoglycemia for people with diabetes and family members alike [10]. A review from 2010 concluded that although there was no conclusive evidence that use of diabetes technologies such as continuous subcutaneous insulin infusion (CSII), continuous glucose monitoring (CGM) and integrated CSII/CGM improved patient-reported outcomes, most studies provided evidence of some advantages and few disadvantages for patient-reported outcomes [27]. In a multi-center prospective pre- and post-study, parents of children with type 1 diabetes reported reduced frequency and difficulty of overall parenting stress and decreased worries about hypoglycemia after transition to continuous subcutaneous insulin infusion therapy [28]. However, no meaningful changes in parental fear of hypoglycemia were found after the introduction of continuous glucose monitoring treatment in children with type 1 diabetes [29]. However, qualitative research among spouses of adults with type 1 diabetes has suggested that continuous glucose monitoring might decrease their worry and need for vigilance about hypoglycemia [30]. The STAR 3 trial compared sensor-augmented pump therapy with optimal conventional therapy (multiple daily injection therapy with self-monitoring of blood glucose) and found significant advantages for worries about hypoglycemia and avoidance in adults with type 1 diabetes and for hypoglycemia avoidance in parents of children with type 1 diabetes [31].

In conclusion, the present large multinational study showed that both overall worries about hypoglycemia and worry about nocturnal events are common among adult family members of adults with diabetes, and that these constructs are closely related to, among other factors, recent hypoglycemic events and family member recognition of hypoglycemic events. Given the association between worries about hypoglycemia and problems with family member support, the impact of hypoglycemia (either actual episodes or worries about future events) on family members and the role family members can play in prevention and care deserves increased clinical and research attention [8]. Diabetes care teams can take a first step in addressing this problem by encouraging adults with diabetes to bring their family members to regular care appointments in order to identify concerns and needs and to include family members in diabetes education [24].

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**AUTHOR CONTRIBUTIONS**

GN, FP, RIGH, SS, NH, AN and MP contributed to the conception and design of the study, analysis and interpretation of the data. GN and FP drafted the first version of the manuscript, in close consultation with MP. GN, FP, RIGH, SS, NH, AN and MP critically revised the manuscript for important intellectual content and approved the final version for publication. All authors take responsibility for the contents of the article.

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**DUALITY OF INTEREST**

GN reports no conflict of interest.

FP has received funding for travel and accommodation to attend DAWN2 International Publication Planning Committee meetings. His research group received a research grant from Novo Nordisk to conduct statistical analyses and describe results of the DAWN2 study and submit this work for publication

RIGH has received funding for travel and accommodation to attend DAWN2 International Publication Planning Committee meetings, but has not received any fee for this work from Novo Nordisk. He has acted as an advisory board member and speaker for Novo Nordisk, and as a speaker for Sanofi-Aventis, Eli Lilly, Otsuka and Bristol-Myers Squibb. He has received grants in support of investigator trials from Novo Nordisk.

SS is an employee of Novo Nordisk.

NH has received funding for travel and accommodation to attend DAWN2 International Publication Planning Committee meetings, but has not received any fee for this work from Novo Nordisk. He has acted as a national advisory board member of DAWN Germany and speaker for Novo Nordisk, and as a speaker for Abbott, Berlin Chemie and Ypsomed. He is advisory board member of Abbott Germany and Ypsomed Switzerland. He has received grants in support of investigator trials from Dexcom, Berlin Chemie and Roche Diagnostics.

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| **Table 1** Overview of measurements |
| **Construct** | **Question/Statement** | **Response options** | **Specifics** |
| **Family member worries about hypoglycemia** |  |  |  |
|  | Overall worries about hypoglycemia | “I am very worried about the risk of him/her having hypoglycemic (low blood sugar) events” | Fully disagree; mainly disagree; mainly agree; fully agree |  |
|  | Worries about nocturnal hypoglycemia | “I am very worried about the risk of him/her having hypoglycemia (low blood sugar) during the night” | Fully disagree; mainly disagree; mainly agree; fully agree |  |
| **Diabetes support by family member** |  |  |  |
|  | Diabetes-related family arguments | “We argue about how he/she chooses to take care of his/her diabetes” | Fully disagree; mainly disagree; mainly agree; fully agree |  |
|  | Family member attending health care provider visits | “You usually attend his/her visits to the health care professionals regarding his/her diabetes” | Disagree strongly; disagree somewhat; neither agree nor disagree; agree somewhat; agree strongly |  |
|  | Family member frustration in providing helpful support | “You are frustrated that you don’t know how to best help the person you live with manage his/her diabetes” | Disagree strongly; disagree somewhat; neither agree nor disagree; agree somewhat; agree strongly |  |
|  | Family member involvement in diabetes care | “Thinking about yourself and the person you live with, please indicate who is responsible for each of the following related to his/her diabetes care.” | You are primarily responsible (allocated a score of 100 for ease of interpretation); you are more responsible than the person you live with (75); you are both equally responsible (50); the person you live with is more responsible (25); the person you live with is primarily responsible (0).  | As the item about injecting medication was posed only to family members of people with diabetes using injections, an overall family member involvement score (0-100) was obtained by dividing the sum of all completed items by the number of completed items.  |
|  | Searching for useful information about diabetes Remembering to take his/her medications Measuring his/her blood sugar Injecting his/her medicationTalking to health care professionals about his/her diabetes care Planning and cooking healthy meals Planning time for exercise or physical activity  |
| **Hypoglycemic events** |  |  |  |
|  | Severe hypoglycemia | “During the past 12 months, approximately how many times has the person you live with had severely low blood sugar such that he/she experienced problems with memory, language, thinking or judgment and was unable to treat himself/herself and needed help from someone to restore blood sugar levels?” | Frequency count | For analyses, categorized asno events, one event, two or more events a |
|  | Non-severe hypoglycemia | “During the past 12 months, on average, how many times has the person you live with had symptomsof low blood sugar such as sweating, weakness, trembling and difficulty concentrating, which he/she could treat him/herself (e.g., by eating a snack which helps bring blood sugar levels back to normal)?”  | At least once a day; at least once a week; several times a month; once a month; less often than once a month (i.e., 2-11 times in the past 12 months); he/she has not had symptoms in the past 12 months | For analyses, categorized as no events, occasional events (less often than once a month, once a month), frequent events (several times a month, at least once a week, at least once a day) |
| **Family member hypoglycemia self-efficacy** | “How confident are you that you know what to do if/when the person you live with has a low blood sugar episode?” | Not at all confident; somewhat confident; fairly confident; very confident; extremely confident |  |
| **Family member difficulties in recognizing hypoglycemia** | “How often can you tell by his/her symptoms that the person you live with is having a low blood sugar episode?” | Always; often; sometimes; rarely; never | Posed only to family members who reported that the person they lived with had experienced hypoglycemia (severe or non-severe) in the previous 12 months |
| **Demographic and clinical covariates** |  |  |  |
|  | Family member sex | “Are you…?” | Male, female |  |
|  | Family member age | “In what year were you born?”  | Four-digit number | For analyses, recalculated as age in years |
|  | Family member educational level | “What is the highest grade of school you completed?” | Country-specific | For analyses, categorized as at least some college education versus no college education |
|  | Family member employment status | “Which of the following best describes your current work situation?”(follow-up question for people working part-time: “You indicated you do not currently work full time. Is this due to the diabetes of the person you live with?”) | Work full time; work part time; not working, but looking for work; not working and not looking for work; unable to work; retired; student; stay-at-home spouse or partner/housewife/husband(follow-up question: yes; no) | For analyses, categorized as working fulltime, working part-time due to diabetes, working part-time due to other reasons, not working). |
|  | Specific relationship with the adult with diabetes  | Not linked to patient sample:If 1 adult with diabetes in household:“Is this person your…?”If ≥2 adults with diabetes in household:“Please think about the person with diabetes who lives with you and in whose diabetes care you are involved most. If you are equally involved in the diabetes care of several adults in your household, please select one person you would like to think about for the remainder of this survey. Is this person your…?” Linked to patient sample:If 1 adult with diabetes in household: “Is this person your…?”If ≥2 adults with diabetes in household:“Please think about the person who referred you to this survey and in whose diabetes care you are involved. Is this person your…?”  | Not linked to patient sample: Spouse/partner; mother; father; sister; brother; son; daughter; other relative; other adult not related to you Linked to patient sample:Spouse/partner; child age 18 or over; parent; other adult relative; other non-relative adult | For analyses, categorized as spouse/partner, parent, other adult |
|  | Other adults with diabetes in household | “Has another adult (age 18 or older) in your household been diagnosed with diabetes by a doctor or health care professional? Please do not include anyone who only had diabetes during pregnancy.”If ≥2 adults with diabetes in household: “How many adults (age 18 or older) in your household have been diagnosed with diabetes by a doctor or health care professional?” | Yes, one adult ; yes, more than one adultFollow-up question: numerical value | For analyses, categorized as 1 adult, ≥2 adults |
|  | Sex of person with diabetes | “Is this person…?” | Male; female |  |
|  | Age of person with diabetes | “How old is this person? If you are not exactly sure, please provide your best estimate.” | Numerical value, years |  |
|  | Diabetes treatment | “What does this person you live with currently use to treat his/her diabetes? Please select all that apply.” | Diet and exercise; alternative medicine; pills or tablets to lower blood sugar; insulin; other diabetes medication by injection; other; none of these | For analyses, categorized as using insulin or non-insulin injectable medication: no, yes |

a To reduce potential bias by outliers and reporting errors

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| **Table 2** Characteristics of adult family members of adults with diabetes |
|  | ***n*  missing** | **All****(n=2,057)** |
| **Demographics family member** |  |  |
|  | Female sex | 0 | 65% (1,338) |
|  | Age, years | 0 | 43 ± 15 (43, 30-55) |
|  | No college education | 45 | 45% (901) |
|  | Working situation | 6 a |  |
|  |  | Working fulltime |  | 42% (871) |
|  |  | Working part-time due to diabetes |  | 2% (36) |
|  |  | Working part-time due to other reasons |  | 12% (243) |
|  |  | Not working |  | 44% (901) |
|  | Main adult with diabetes cared for | 17 |  |
|  |  | Spouse/partner |  | 41% (834) |
|  |  | Parent |  | 37% (746) |
|  |  | Other adult b |  | 23% (460) |
|  | ≥ 2 adults with diabetes in household | 4 | 6% (133) |
| **Characteristics adult with diabetes** |  |  |
|  | Female sex | 0 | 47% (959) |
|  | Age, years | 0 | 59 ± 15 (60, 51-70) |
|  | Treatment with insulin and/or non-insulin injectable medication c | 0 | 48% (982) |
| **Frequency of hypoglycemic events** |  |  |
|  | Severe hypoglycemic events in past 12 months | 461 |  |
|  |  | No severe hypoglycemic events |  | 57% (911) |
|  |  | 1 severe hypoglycemic event |  | 12% (191) |
|  |  | ≥2 severe hypoglycemic events |  | 31% (494) |
|  | Non-severe hypoglycemic events in past 12 months | 154 |  |
|  |  | No non-severe hypoglycemic events |  | 27% (505) |
|  |  | Occasional non-severe hypoglycemic events d |  | 41% (779) |
|  |  | Frequent non-severe hypoglycemic events e |  | 33% (619) |
| **Family member hypoglycemia self-efficacy** | 123 |  |
|  | Not at all confident |  | 8% (149) |
|  | Somewhat confident |  | 25% (476) |
|  | Fairly confident |  | 29% (566) |
|  | Very confident |  | 22% (421) |
|  | Extremely confident |  | 17% (322) |
| **Family member recognition of hypoglycemia** | 479 f |  |
|  | Always |  | 12% (191) |
|  | Often |  | 23% (359) |
|  | Sometimes |  | 37% (576) |
|  | Rarely |  | 22% (344) |
|  | Never |  | 7% (108) |
| **Family member overall worries about hypoglycemia (“I am very worried...”)** | 104 |  |
|  | Fully disagree |  | 15% (292) |
|  | Mainly disagree |  | 24% (464) |
|  | Mainly agree |  | 37% (718) |
|  | Fully agree |  | 25% (479) |
| **Family member worries about nocturnal hypoglycemic events (“I am very worried…”)** | 103 |  |
|  | Fully disagree |  | 17% (334) |
|  | Mainly disagree |  | 23% (455) |
|  | Mainly agree |  | 33% (651) |
|  | Fully agree |  | 26% (514) |
| **Diabetes-related family arguments (“We argue…”)** | 67 |  |
|  | Fully disagree |  | 32% (630) |
|  | Mainly disagree |  | 25% (493) |
|  | Mainly agree |  | 26% (515) |
|  | Fully agree |  | 18% (352) |
| **Family member attending of health care provider visits (“You usually attend…”)** | 7 |  |
|  | Disagree strongly |  | 16% (326) |
|  | Disagree somewhat |  | 14% (294) |
|  | Neither agree nor disagree |  | 16% (321) |
|  | Agree somewhat |  | 28% (570) |
|  | Agree strongly |  | 26% (539) |
| **Family member frustration in providing helpful support (“You are frustrated…”)** | 11 |  |
|  | Disagree strongly |  | 22% (460) |
|  | Disagree somewhat |  | 20% (402) |
|  | Neither agree nor disagree |  | 21% (424) |
|  | Agree somewhat |  | 25% (520) |
|  | Agree strongly |  | 12% (240) |
| **Family member involvement in diabetes care** |  |  |
|  | Family member responsibility g | 406 | 42 ± 23 (42, 25-54) |

Values are % (n) or mean ± SD (median, interquartile range); some percentages may not add up to 100% due to rounding; a including two persons who indicated to work part-time, but did not specify whether this was due to the diabetes of the person they lived with; b sibling, child, other relative, other non-related adult; c n=893 using insulin but not non-insulin injectable medication, n=45 using non-insulin injectable medication but not insulin, n=44 using both insulin and non-insulin injectable medication; d less often than once a month, once a month; e several times a month, at least once a week, at least once a day; f n=419 family members indicated that the person they lived with had not experienced any hypoglycemic event (severe or non-severe) in the past 12 months and were consequently not asked the question about family member hypoglycemia recognition; g 0-100 scale, with a higher score representing higher family member responsibility.

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| **Table 3** Hierarchical ordinal regression analyses examining the correlates of (a) family member overall worries about hypoglycemia (n=1,886) and (b) family member worries about nocturnal hypoglycemic events (n=1,886) |
|  | **Overall WORRIES ABOUT HYPOGLYCEMIA** | **WORRIES ABOUT Nocturnal hypoglycemia**  |
|  | **Final model** **(model 4)** | **Final model** **(model 4)** |
| **1. Demographics**  |  |  |
|  | Family member is female | 1.40 (1.15-1.71)b | 1.33 (1.09-1.62)b |
|  | Age of family member, years | 1.01 (1.01-1.02)b | 1.01 (1.00-1.02) |
|  | Family member has no college education | 1.35 (1.11-1.63)b | 1.15 (0.95-1.40) |
|  | Family member working fulltime | Ref | Ref |
|  | Family member working part-time due to diabetes | 1.53 (0.78-2.99) | 1.89 (0.96-3.70) |
|  | Family member working part-time due to other reasons | 0.90 (0.68-1.20) | 1.01 (0.76-1.34) |
|  | Family member not working | 1.11 (0.91-1.35) | 1.20 (0.99-1.46) |
|  | Country d |  |  |
|  | Main adult with diabetes cared for |  |  |
|  |  | Spouse/partner | Ref | Ref |
|  |  | Parent | 2.00 (1.51-2.63)c | 1.70 (1.29-2.24)c |
|  |  | Other adult | 1.49 (1.13-1.96)b | 1.30 (0.99-1.71) |
|  | ≥ 2 adults with diabetes in household | 1.05 (0.73-1.49) | 1.03 (0.72-1.47) |
|  | Adult with diabetes is female | 1.14 (0.94-1.37) | 1.08 (0.89-1.30) |
|  | Age of adult with diabetes, years | 0.99 (0.98-0.99)c | 0.99 (0.99-1.00)a |
| **2. Diabetes treatment** |  |  |
|  | Treatment with insulin or non-insulin injectable medication | 1.24 (1.04-1.49)a | 1.55 (1.30-1.86)c |
| **3. Frequency of hypoglycemic events** |  |  |
|  | Severe hypoglycemia, categories e |  |  |
|  |  | No severe hypoglycemic events | Ref | Ref |
|  |  | 1 severe hypoglycemic event | 2.04 (1.48-2.82)c | 1.86 (1.35-2.56)c |
|  |  | ≥2 severe hypoglycemic events | 1.96 (1.54-2.51)c | 1.95 (1.53-2.49)c |
|  | Non-severe hypoglycemia, categories e |  |  |
|  |  | No non-severe hypoglycemic events | Ref | Ref |
|  |  | Occasional non-severe hypoglycemic events  | 2.55 (1.99-3.27)c | 2.56 (2.00-3.28)c |
|  |  | Frequent non-severe hypoglycemic events  | 3.96 (3.00-5.23)c | 3.62 (2.75-4.77)c |
| **4. Family member hypoglycemia self-efficacy** e |  |  |
|  | Not at all confident | Ref | Ref |
|  | Somewhat confident | 1.23 (0.84-1.79) | 1.20 (0.82-1.75) |
|  | Fairly confident | 1.31 (0.89-1.92) | 1.15 (0.79-1.68) |
|  | Very confident | 1.12 (0.75-1.66) | 0.98 (0.66-1.46) |
|  | Extremely confident | 0.91 (0.61-1.37) | 0.91 (0.61-1.37) |
|  |  |  |  |
| Nagelkerke Pseudo R2 model 1/2/3/4 | 0.15/0.16/0.26/0.27 | 0.15/0.18/0.27/0.27 |
| Model fit improvement |  |  |
|  | Model 1 versus empty model | X2(27)=285, *p*<0.001 | X2(27)=287, *p*<0.001 |
|  | Model 2 versus model 1 | X2(1)=28, *p*<0.001 | X2(1)=57, *p*<0.001 |
|  | Model 3 versus model 2 | X2(6)=217, *p*<0.001 | X2(6)=199, *p*<0.001 |
|  | Model 4 versus model 3 | X2(5)=8, *p*=0.14 | X2(5)=6, *p*=0.35 |

Values are OR (95% CI); Ref = reference category; a *p*<0.05; b *p*<0.01; c *p*<0.001; d Individual country coefficients not reported for the sake of parsimony; e Missing values entered as separate category (not shown).

Model 1: Demographics;

Model 2: Demographics + diabetes treatment;

Model 3: Demographics + diabetes treatment + frequency of hypoglycemic events;

Model 4: Demographics + diabetes treatment + frequency of hypoglycemic events + hypoglycemia self-efficacy.

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| **Table 4** Ordinal regression analyses (for arguments, visits, frustration) and linear regression analysis (for involvement) examining the association between family member overall worries about hypoglycemia and support outcomes d |
|  | **Diabetes-related family arguments** **(n=1,921)** | **Attending health care provider visits** **(n=1,981)** | **Frustration in providing helpful support** **(n=1,977)** | **Family member involvement in diabetes care (n=1,593)** |
|  | Family member is female | 1.24 (1.02-1.51)a | 1.17 (0.97-1.41) | 0.87 (0.72-1.04) | 0.13c |
|  | Age of family member, years | 1.00 (0.99-1.01) | 1.01 (1.00-1.02)a | 0.99 (0.98-1.00)a | -0.08a |
|  | Family member has no college education | 1.10 (0.91-1.33) | 1.17 (0.97-1.41) | 1.02 (0.84-1.22) | 0.01 |
|  | Family member working fulltime | Ref | Ref | Ref | Ref |
|  | Family member working part-time due to diabetes | 0.90 (0.47-1.72) | 2.92 (1.46-5.81)b | 1.61 (0.86-2.99) | 0.12c |
|  | Family member working part-time due to other reasons | 1.01 (0.76-1.34) | 0.86 (0.66-1.13) | 1.00 (0.76-1.31) | 0.02 |
|  | Family member not working | 1.03 (0.85-1.24) | 1.01 (0.84-1.21) | 0.95 (0.79-1.15) | 0.04 |
|  | Country e |  |  |  |  |
|  | Main adult with diabetes cared for |  |  |  |  |
|  |  | Spouse/partner | Ref | Ref | Ref | Ref |
|  |  | Parent | 1.04 (0.79-1.37) | 1.02 (0.78-1.32) | 1.17 (0.90-1.52) | 0.02 |
|  |  | Other adult | 1.23 (0.94-1.61) | 0.88 (0.68-1.15) | 1.13 (0.87-1.47) | 0.01 |
|  | ≥ 2 adults with diabetes in household | 0.92 (0.65-1.31) | 1.00 (0.72-.1.40) | 0.83 (0.59-1.16) | 0.05a |
|  | Adult with diabetes is female | 0.74 (0.61-0.89)b | 1.18 (0.99-1.41) | 0.93 (0.78-1.11) | 0.01 |
|  | Age of adult with diabetes, years | 1.00 (0.99-1.00) | 1.01 (1.00-1.02)a | 0.99 (0.99-1.00) | 0.17c |
|  | Treatment with insulin or non-insulin injectable medication | 1.16 (0.97-1.39) | 1.03 (0.87-1.23) | 1.21 (1.02-1.43)a | -0.03 |
|  | Severe hypoglycemia, categories f |  |  |  |  |
|  |  | No severe hypoglycemic events | Ref | Ref | Ref | Ref |
|  |  | 1 severe hypoglycemic event | 1.43 (1.04-1.96)a | 1.48 (1.08-2.01)a | 1.28 (0.94-1.74) | 0.05a |
|  |  | ≥2 severe hypoglycemic events | 1.39 (1.09-1.77)b | 1.24 (0.98-1.57) | 1.14 (0.90-1.44) | 0.10b |
|  | Non-severe hypoglycaemia, categories f |  |  |  |  |
|  |  | No non-severe hypoglycemic events | Ref | Ref | Ref | Ref |
|  |  | Occasional non-severe hypoglycemic events  | 0.96 (0.75-1.23) | 0.87 (0.68-1.10) | 1.34 (1.05-1.70)a | -0.08a |
|  |  | Frequent non-severe hypoglycemic events  | 1.14 (0.86-1.51) | 0.94 (0.72-1.22) | 1.91 (1.46-2.50)c | -0.03 |
|  | Family member hypoglycemia self-efficacy f |  |  |  |  |
|  |  | Not at all confident | Ref | Ref | Ref | Ref |
|  |  | Somewhat confident | 1.30 (0.90-1.86) | 1.64 (1.16-2.31)b | 0.72 (0.51-1.01) | 0.05 |
|  |  | Fairly confident | 1.18 (0.82-1.71) | 1.70 (1.20-2.42)b | 0.54 (0.38-0.77)b | 0.05 |
|  |  | Very confident | 0.90 (0.61-1.32) | 2.01 (1.39-2.89)c | 0.46 (0.32-0.66)c | 0.09a |
|  |  | Extremely confident | 0.90 (0.61-1.35) | 2.93 (2.01-4.28)c | 0.33 (0.23-0.48)c | 0.09a |
|  | Family member overall worries about hypoglycemia f |  |  |  |  |
|  |  | Fully disagree | Ref | Ref | Ref | Ref |
|  |  | Mainly disagree | 1.60 (1.18-2.17)b | 1.15 (0.87-1.53) | 1.66 (1.24-2.21)b | 0.02 |
|  |  | Mainly agree | 2.76 (2.05-3.71)c | 1.18 (0.89-1.56) | 2.43 (1.83-3.23)c | 0.06 |
|  |  | Fully agree | 3.45 (2.50-4.74)c | 1.84 (1.36-2.49)c | 3.72 (2.74-5.06)c | 0.04 |
|  |  |  |  |  |  |
|  | Nagelkerke Pseudo R2 / R2 | 0.23 | 0.17 | 0.19 | 0.20 |
|  | Model fit improvement (fully adjusted model compared to model without worries about hypoglycemia) | *X*2(4)=72, *p*<0.001 | *X*2(4)=21, *p*<0.001 | *X*2(4)=74, *p*<0.001 | *F*(4)=2, *p*=0.09 |

Values are OR (95% CI) or standardized beta values; Ref = reference category; a *p*<0.05; b *p*<0.01; c *p*<0.001; d only results from the fully adjusted models are displayed; e individual country coefficients not reported for the sake of parsimony; f missing values entered as separate category (not shown).