ann. behav. med. (2021) 55:123–132
DOI: 10.1093/abm/kaaa038

REGULAR ARTICLE

Spousal Influence on Diabetes Self-care: Moderating Effects of Distress and Relationship Quality on Glycemic Control

Emily C. Soriano, MA[1] James.M. Lenhard, MD[2] Jeffrey S. Gonzalez, PhD[5] Howard Tennen, PhD[6] Sy-Miin Chow, PhD[7] Amy K. Otto, PhD[1,9] Christine Perndorfer, MS[1] Biing-Jiun Shen, PhD[8] Scott D. Siegel, PhD[3] Jean-Philippe Laurenceau, PhD[1,4]

Published online: 3 June 2020

Abstract

Background Spouses often attempt to influence patients' diabetes self-care. Spousal influence has been linked to beneficial health outcomes in some studies, but to negative outcomes in others.

Purpose We aimed to clarify the conditions under which spousal influence impedes glycemic control in patients with type 2 diabetes. Spousal influence was hypothesized to associate with poorer glycemic control among patients with high diabetes distress and low relationship quality.

Methods Patients with type 2 diabetes and their spouses (N = 63 couples) completed self-report measures before patients initiated a 7-day period of continuous glucose monitoring. Mean glucose level and coefficient of variation (CV) were regressed on spousal influence, diabetes distress, relationship quality, and their two- and three-way interactions.

Results The three-way interaction significantly predicted glucose variability, but not mean level. Results revealed a cross-over interaction between spousal influence and diabetes distress at *high* (but not *low*) levels of relationship quality, such that spousal influence was associated with less variability among patients with low distress, but more among those with high distress. Among patients with high distress and low relationship quality, a 1 *SD* increase in spousal influence predicted a difference roughly equivalent to the difference between the sample mean CV and a CV in the unstable glycemia range.

Conclusions This was the first study to examine moderators of the link between spousal influence and glycemic control in diabetes. A large effect was found for glucose variability, but not mean levels. These novel results highlight the importance of intimate relationships in diabetes management.

Keywords: Continuous glucose monitoring · Diabetes distress · Relationship quality · Social control · Type 2 diabetes

✉ Emily C. Soriano
esoriano@udel.edu

1 Department of Psychological & Brain Sciences, University of Delaware, 108 Wolf Hall, Newark, DE 19716, USA

2 Section of Endocrinology and Metabolism, Christiana Care Health System, Wilmington, DE, USA

3 Value Institute, Christiana Care Health System, Wilmington, DE, USA

4 Helen F. Graham Cancer Center, Christiana Care Health System, Wilmington, DE, USA

5 Ferkauf Graduate School of Psychology, Yeshiva University; Departments of Medicine and Epidemiology & Population Health, Albert Einstein College of Medicine, New York, NY, USA

6 Department of Community Medicine and Department of Psychiatry, University of Connecticut School of Medicine, Farmington, CT, USA

7 Department of Human Development and Family Studies, Pennsylvania State University, State College, PA, USA

8 Division of Psychology, School of Humanities and Social Sciences, Nanyang Technological University, Singapore

9 Present address: Moffitt Cancer Center, Tampa, FL, USA

Type 2 diabetes mellitus self-care is critical for preventing potentially fatal complications [1]. Diabetes self-care describes the patient's ability to adapt to ongoing demands of diabetes via behavioral and lifestyle change (e.g., diet, exercise). While self-care interventions are effective in the short term, there is limited support for the maintenance of effects over time [2, 3]. The increasing public health burden of type 2 diabetes [4]—the seventh

leading cause of death in the USA—signals a clear need for interventions that target mechanisms of long-term behavior change.

Several lines of research highlight the potential impact that intimate partners (hereafter termed *spouses*, regardless of marital status) may have on type 2 diabetes care. On a practical level, diabetes management involves an array of daily activities typically shared with and influenced by spouses (e.g., preparing and eating meals). Empirically, intimate relationship functioning has strong links to known psychosocial predictors of diabetes self-care and glycemic control [5], including stress [6], social isolation [7, 8], and self-efficacy [9]. For example, the spouse's supportive involvement in diabetes management has been linked to better self-care [10, 11] and glycemic control [12]. Relationship quality has also been linked to a lower incidence of diabetes [13, 14] and better glycemic control among people with diabetes (PWD [15]).

Taken together, this suggests that including spouses in diabetes self-management interventions would enhance the potency and maintenance of treatment benefits. However, to date, there have been few evaluations of couple-based diabetes interventions (for a recent exception, see [16]). Reviews of couple-focused interventions offer reasons for their lack of uptake—studies have seldom explicated the nature of spousal influence, interpersonal intervention targets, or theoretical underpinnings [17, 18]. A critical barrier to improving diabetes interventions by involving spouses is that we currently lack an understanding of precisely how and under what conditions spouses may either facilitate or impede diabetes self-care. Knowledge of when spousal influence should be encouraged or avoided is essential to build on prior work [16–18] and inform how to structure spouse involvement to enhance intervention efficacy. Note that we use the term *spousal influence* to refer to any spouse behavior motivated by an intention to alter the PWD's health behavior (e.g., encouragement, criticism).

Several observational studies suggest that spousal influence is not always associated with positive health outcomes for PWD. Some studies have found that spousal influence is linked to enhanced diabetes self-care behavior, such as better diet adherence [19], while others report negative effects of spousal influence, such as less physical activity [20, 21]. Some research has attempted to categorize forms of spousal influence—often termed *social control tactics* in this context—as positive (health-promoting) or negative (health-compromising [22]). However, this work has failed to show that positive tactics are consistently linked to desirable health outcomes, nor negative tactics to undesirable outcomes—for example, positive and negative influence were *both* associated with poorer diet adherence in PWD [21]. Moreover, it is unclear which forms of spousal influence should be considered positive versus negative; intuitively, it seems likely that people differ from one another in how they tend to respond (emotionally and behaviorally) to the same spousal influence behavior [22]. For example, one PWD may perceive a spouse's healthy snack suggestion as supportive and caring, while another may perceive the same form of spousal influence as critical. This perspective highlights the need to consider moderating contextual factors, which then could be used to screen and target PWD for whom spousal influence on diabetes treatment would be (contra)indicated—such an advance would have a significant, positive impact on clinical practice decisions and research in diabetes care. Currently, the question of which PWD would benefit from a couple-focused intervention approach remains unstudied.

Are Effects of Spousal Influence on Diabetes Management Clinically Meaningful?

Although the extant literature supports a link between spousal influence and subjective indicators of disease management (for a review, see [22]), it is unclear whether this translates to clinically significant change in objective health outcomes. The few studies that have examined the effects of spousal influence on hemoglobin A1c (HbA1c) report mixed results [23–28]. HbA1c, a primary indicator of glycemic control in diabetes, is obtained in a simple blood test and reflects average levels of glucose over the past 2–3 months. Glucose variability is increasingly viewed as another primary indicator of glycemic control [29–31]. Variability has been shown to predict downstream complications of diabetes (e.g., microvascular complications [29, 32–34) and, in some cohorts, variability was an independent predictor of morbidity and mortality, irrespective of mean glucose levels [32–34]. Continuous glucose monitors (CGMs) allow objective, real-time examination of both mean glucose level (reflected in HbA1c) *and* glucose variability. However, CGM-based indices of glycemic control have not yet been applied to the study of spousal influence on diabetes management.

The Current Study

In this observational study, we examined two contextual moderators—diabetes distress and relationship quality—of the association between spousal influence and PWD's glycemic control. Diabetes distress is defined as "the negative emotional responses (overwhelmed, hopeless, and helpless) and perceived burden related to diabetes" [35], and has been linked to poorer glycemic control, treatment adherence, and self-efficacy [35–37]. Diabetes distress is hypothesized to bias the PWD's response to

Table 1. Descriptive statistics and bivariate correlations of study variables

	1	2	3	4	5	6	7
1. Spousal influence[a]	—						
2. Diabetes distress	.384**	—					
3. Relationship quality	−.164	−.196	—				
4. Disease duration (years)	.037	.205	.130	—			
5. Insulin use[b]	.111	.280*	−.159	.289*	—		
6. Mean glucose	.200	.357**	−.177	.297*	.454***	—	
7. Glucose CV	.148	.259*	−.048	.269*	.282*	.223[†]	—
M	2.643	2.078	40.423	12.410	0.550	157.237	28.780
SD	0.933	0.910	5.665	7.981	0.498	30.486	7.958
Observed range	1.00–5.25	1.00–4.59	20–45	0.75–33	—	103–252	16–52

Note. $N = 63$. There were no missing data; glycemic control outcomes were based on aggregate CGM readings, of which 95% were available (5% missing due to, e.g., sensor failure or noncompliance). *CGM* continuous glucose monitor; *CV* coefficient of variation; *PWD* people with diabetes.

[a]All other self-report measures were reported by PWD rather than spouses.

[b]Insulin use is a binary variable, where 1 = yes and 0 = no.

[†]$p < .10$.

*$p < .05$.

**$p < .01$.

***$p < .001$.

spousal influence toward negative thoughts and feelings about oneself; for example, distressed PWD may be more likely to interpret their spouse's involvement as a reminder of the burden of diabetes. Low relationship quality, or global dissatisfaction with one's relationship, is also hypothesized to elicit a negative response to spousal influence, as it may lead PWD to appraise spousal influence as intrusive or critical rather than supportive. Conversely, PWD who are generally content with both their diabetes management and relationship may be better equipped to take in their spouse's control attempts as supportive, well-intended, and a prompt to attend to or modify their diabetes self-care behavior, thus facilitating glycemic control. To model the dyadic process involving both partners [38, 39], we examined *actual* or *enacted* spousal influence (i.e., spouses' report of their own attempts to influence PWD's health behavior) rather than that *perceived* by PWD.

Method

Participants and Procedure

Adults with type 2 diabetes and their spouses were recruited between 2016 and 2017 for a larger Institutional Review Board-approved longitudinal observational study from an endocrinology clinic in the mid-Atlantic USA. Participants were eligible if they met the following criteria: (a) at least 18 years old, (b) diagnosed with type 2 diabetes ≥6 months prior, (c) in a committed romantic relationship with a partner who did *not* have diabetes and also agreed to participate. PWD were excluded if they were (a) diagnosed with any comorbid condition with <1-year life expectancy, (b) on anticoagulant therapy (except aspirin), (c) treated for an infection ≤4 weeks prior, (d) treated with an insulin pump, or (e) pregnant. Because the study was funded by an exploratory grant mechanism, a formal power analysis was not conducted as the focus was on sensible accurate parameter estimation that would form the basis of a future Monte Carlo simulation-based power analysis to support a high-power replication.

Medical records were screened to identify potentially eligible PWD, who were then sent a letter and phoned to verify eligibility. Of the 1,848 potentially eligible PWD, 785 actively declined (most commonly cited reasons being a lack of interest and too much work), 758 passively declined (i.e., were unable to be reached after three or more contact attempts), and 242 were ineligible. A final sample of 63 couples ($n = 63$ patients with type 2 diabetes) agreed to participate and provided informed consent. Participation in this year-long study took place between 2016 and 2018. All couples were heterosexual. Two thirds of PWD were male and 97% non-Hispanic/Latino. In terms of race, 70% of PWD were Caucasian, 24% African American, 4% other/multiracial, and 2% Asian. The majority (76%) of PWD reported an annual

household income over $60,000. The average PWD age was 61 years (*SD* = 10). On average, their HbA1c was 7.80% (62 mmol/mol; *SD* = 1.40%) and weight status was obese (body mass index *M* = 33.11, *SD* = 7.30). About half (55%) of patients were on insulin and the average time elapsed since diabetes diagnosis, per electronic medical record, was 12.41 years (*SD* = 7.98; see also Table 1).

Continuous Glucose Monitor

During a baseline visit, PWD were equipped with a Dexcom G4 CGM system and completed a series of self-report measures, as described below. The Dexcom G4 CGM is approved by the U.S. Food and Drug Administration to obtain glucose readings via interstitial fluid every 5 min 24 hr per day for up to 7 consecutive days and detects glucose levels between 40 and 400 mg/dL. PWD wore the CGM for the following 7 days, then returned to the clinic for device removal. Throughout the recording period, this sample of PWD was *blinded* to CGM feedback (i.e., glucose readings) and calibrated the device every 12 hr by entering a finger-stick glucose meter reading. PWD were trained and demonstrated proficiency in the CGM maintenance and calibration procedures at baseline. On average, 1,917 of 2,016 possible CGM readings were obtained per PWD, reflecting 95% compliance. The correlation between CGM-based mean glucose and baseline HbA1c was $r = .70$, $p < .001$.

Self-report Measures

Spouses reported their involvement in PWD diabetes self-care on the Health-Related Social Control Tactic Scale [39]. Spouses indicated how often they use 28 behaviors to influence the PWD's health-related behavior (1 = *Never*; 7 = *At least once a day*). The items ranged from warm/gentle (e.g., *Praise or compliment him/her*) to harsh/critical (e.g., *Try to make him/her feel guilty*); all items were averaged to create a single composite score. Cronbach's alpha indicated good reliability in this sample (α = .91) and past work that also provides some evidence of validity [40, 41]. Note that research on this measure often distinguishes "positive" from "negative" control tactics; however, several studies have failed to find a two-factor structure of this scale, and empirical tests of distinct effects of positive versus negative social control on health behavior have yielded inconsistent support for this conceptualization [42, 43]. Thus, we collapsed across all control tactics and conceptualize this composite as an index of overall frequency of attempts by spouses to influence PWD health behavior, an approach consistent with some past work [38, 40, 44].

The Diabetes Distress Scale provided an index of overall diabetes-related distress [45]. The Diabetes Distress Scale has demonstrated strong reliability and validity in past work [45, 46]. PWD were asked to *Please rate the degree to which the following are currently problematic for you* with regard to 17 items, which were rated from 1 (*No problem*) to 6 (*Serious problem*). Sample items include *Feeling that diabetes is taking up too much of my mental and physical energy every day* and *Feeling that diabetes controls my life.* Items were averaged (possible range: 1–6), and the resulting composite had high internal consistency in this study (α = .92). A composite score ≥3 is indicative of clinically significant diabetes distress [36], which is about 1 *SD* above the current sample mean.

PWD completed the Quality of Marriage Index (QMI), a commonly used measure of global relationship quality with good reliability and validity [47, 48]. Five items (e.g., *We have a good relationship*) were rated from 1 (*Very strongly disagree*) to 7 (*Very strongly agree*). A sixth item (*All things considered, what degree of happiness best describes your relationship?*) was rated from 1 (*Unhappy*) to 10 (*Perfectly happy*). Items were summed, with higher scores indicating higher quality (possible range: 6–45). Reliability of the QMI in the present study was high (α = .95). A total score ≤29 is considered indicative of clinically significant relationship distress [48].

Statistical Analysis

Person-level indices of mean glucose level and glucose variability were derived using all available CGM data. In line with recent consensus recommendations [29] and prior research (e.g., [32]), our chosen glucose variability metric was the coefficient of variation (CV), which is equal to the standard deviation of a PWD's CGM-based glucose readings divided by his/her mean. Stable glycemic variability has been defined as CV <36%, and unstable as CV ≥36% [29, 49].

Diabetes duration in years and insulin use (yes/no), as indicators of overall disease severity, were included as covariates in all models to reduce potential confounding effects of individual differences in severity and diabetes self-care regime. Continuous (quantitative) variables were kept and analyzed in their original form. All predictors and covariates were mean centered prior to entry. The three-way interaction and all lower-level interactions among spousal influence, diabetes distress, and relationship quality were then computed. Mean glucose level and glucose CV were examined as outcomes using path modeling in *Mplus* version 8.2 [50]. This maximum likelihood-based approach accommodates the simultaneous estimation of multiple outcomes (i.e., glucose mean and CV) within the same model. The outcomes were initially regressed on the three-way interaction, all lower-level interactions, all marginal main effects, and covariates.

Nonsignificant interactions were removed in subsequent models. To probe and plot interaction effects, we operationalized low and high values of each moderator as 1 *SD* below and above the mean (centered on zero). Low/high values of diabetes distress were thus defined as ±0.9; note that high distress is approximately equal to the recommended clinical cutoff [36]. Low/high relationship quality was defined as ±5.6; in the current sample, the cutoff for clinically significant relationship distress [48] was about 2 *SD* below the mean.

Results

Preliminary Results

Descriptive statistics and bivariate correlations are shown in Table 1. Spouses of PWD with more diabetes distress tended to endorse more involvement in their self-care. Diabetes distress, but not relationship quality, was significantly correlated with greater spousal influence (r = .384). The zero-order correlations between diabetes distress and mean glucose levels (r = .357) as well as CV (r = .259) were also significant and positive.

Mean Glucose

Path modeling results for mean glucose level are shown in the top half of Table 2. The three-way interaction between spousal influence, diabetes distress, and relationship quality was not statistically significant (p = .477). The three-way interaction and nonfocal two-way interaction (i.e., diabetes distress by relationship quality) were subsequently removed, leaving only the two-way interactions between spousal influence and each moderator; neither two-way interaction was statistically significant (both ps > .7). Thus, all interaction terms were excluded in the final model. As shown in Table 2, neither spousal influence (p = .538), diabetes distress (p = .131), nor relationship quality (p = .369) was a statistically significant predictor of mean glucose. The only statistically significant predictor of mean glucose was insulin use, which was associated with higher glucose levels over the monitoring period (p = .004).

Glucose Variability (CV)

Path modeling results for glucose CV are shown in the bottom half of Table 2. Beginning with main effects, there was a significant (p = .020) marginal main effect of spousal influence on CV, indicating that, for a one-unit increase in spousal influence, the model predicted over a 2.5% increase in glucose CV (for those at mean levels of diabetes distress and relationship quality). Insulin use was not significantly associated with greater variability (p = .065). Diabetes duration predicted significantly greater glucose variability (p = .016).

Several two-way interaction effects were also significant. The interaction between spousal influence and diabetes distress was significant (p = .008) and positive, indicating that diabetes distress intensified or strengthened the positive effect of spousal influence on CV (at mean levels of relationship quality); in other words, when PWD reported more diabetes distress, spousal influence was more strongly associated with more glucose variability. The interaction between spousal influence and relationship quality was not significant (p = .911). Although not of focal interest, the interaction between diabetes distress and relationship quality was significant (p = .021) and negative, such that greater relationship quality attenuated the positive link between diabetes distress and variability (at average levels of spousal influence).

Finally, as predicted, the three-way interaction between spousal influence, diabetes distress, and relationship quality was a statistically significant predictor of glucose CV (p < .001). To probe and interpret this

Table 2. Path modeling results with mean glucose level and glucose variability as outcomes

Effect	Estimate	*SE*	*p*
Outcome: mean glucose level			
Spousal influence (SI)	2.315	3.756	.538
Diabetes distress (DD)	6.110	4.050	.131
Relationship quality (RQ)	−0.538	0.599	.369
Disease duration	0.669	0.435	.124
Insulin use	19.963**	6.999	.004
Outcome: glucose coefficient of variation (CV)			
Spousal influence (SI)	2.574*	1.108	.020
Diabetes distress (DD)	0.460	1.076	.669
Relationship quality (RQ)	−0.331†	0.180	.066
SI × DD	3.165**	1.202	.008
SI × RQ	−0.025	0.224	.911
DD × RQ	−0.513*	0.223	.021
SI × DD × RQ	0.645***	0.167	<.001
Disease duration	0.277*	0.115	.016
Insulin use	3.378†	1.830	.065

Note. Unstandardized regression coefficients shown. For mean glucose level (top panel), nonsignificant interactions were removed from the final model presented here.

$^{\dagger}p$ < .10.

*p < .05.

**p < .01.

***p < .001.

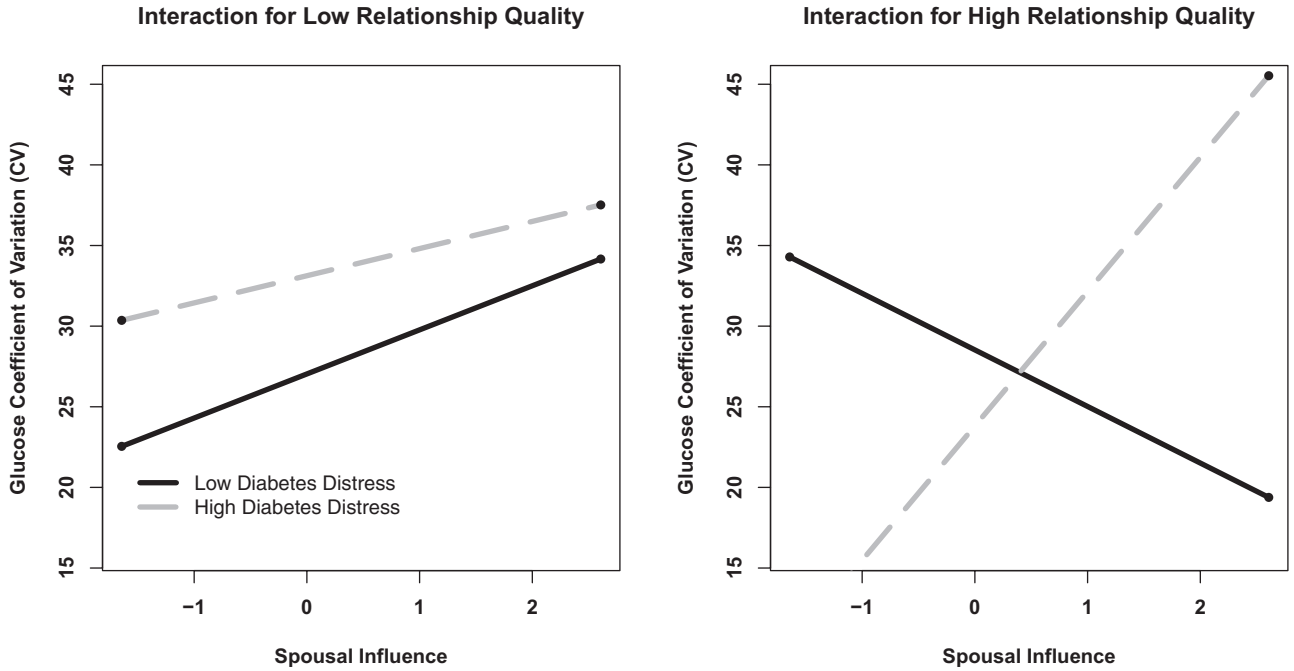

Fig. 1. Plots depicting three-way interaction between spousal influence, diabetes distress, and relationship quality (all mean centered) in the prediction of glucose variability (coefficient of variation [CV]). The *x*-axes span the observed range of spousal influence; the *y*-axes span approximately ±2 *SD* of glucose CV. The interaction between spousal influence and diabetes distress is shown at low levels of relationship quality (mean −1 *SD*; left panel) and high levels of relationship quality (mean +1 *SD*; right panel). Left panel: the simple slope of CV on spousal influence at low levels of diabetes distress (mean −1 *SD*; black solid line) is $b = 3.161$ (2.391), $z = 1.322$, $p = .186$, and at high levels of diabetes distress (mean +1 *SD*; gray dashed line) is $b = 2.271$ (1.680), $z = 1.352$, $p = .176$. Right panel: the simple slope of CV on spousal influence at low levels of diabetes distress is $b = -3.773$ (1.844), $z = -2.047$, $p = .041$, and at high levels of diabetes distress is $b = 8.638$ (2.676), $z = 3.228$, $p = .001$.

three-way interaction, the two-way interaction between spousal influence and diabetes distress was plotted for low and high levels of relationship quality, as shown in Fig. 1. At low levels of relationship quality, there was little evidence of an interaction between spousal influence and diabetes distress in the prediction of glucose CV (Fig. 1, left panel). That is, among PWD with low relationship quality, spousal influence was not significantly associated with glucose CV, regardless of diabetes distress levels ($p = .186$ and .176).

At high levels of relationship quality, Fig. 1 (right panel) depicts a disordinal (cross-over) interaction between spousal influence and diabetes distress. At low levels of diabetes distress and high relationship quality—theoretically, the most "ideal" or adaptive of the four plotted conditions—more frequent spousal influence was associated with *lower* glycemic variability ($p = .041$). However, among PWD with high levels of diabetes distress and high relationship satisfaction, more frequent spousal influence was associated with significantly *greater* glycemic variability ($p = .001$). The confidence bands and regions of significance for these simple slopes are shown in Fig. 2.

The size of this three-way interaction effect on glucose CV is noteworthy (standardized $\beta = 0.862$). As illustrated in Fig. 1 (right panel), a one-unit increase in spousal influence predicted nearly a *nine-unit increase* in (raw) glucose CV—a shift exceeding 1 *SD*. The R^2 for this model is .333, suggesting a large effect size for this set of predictors. The change in R^2 compared with a model only containing covariates (insulin use and diabetes duration) was .215 and statistically significant, $F(7,53) = 2.441$, $p = .030$. Furthermore, the R^2 change compared with a model containing covariates and focal predictor main effects, but no interactions, was .185 and also significant, $F(4,53) = 3.675$, $p = .010$, suggesting that the interactions significantly improved prediction of glucose CV.

In a post hoc sensitivity analysis, the focal three-way interaction remained a statistically significant predictor of CV after including the diet and exercise adherence subscales of the Summary of Diabetes Self-Care Activities [51] as additional covariates. We also re-ran our main models after controlling for PWD perceptions of spousal influence (using parallel versions of the same 28 items administered to spouses), thus allowing the focal spousal influence predictor to reflect effects above and beyond any overlap or agreement between partners' report of the same construct (the correlation between PWD- and spouse-reported spousal influence was $r = .287$). The pattern of results for mean glucose and glucose CV did not change and the key three-way

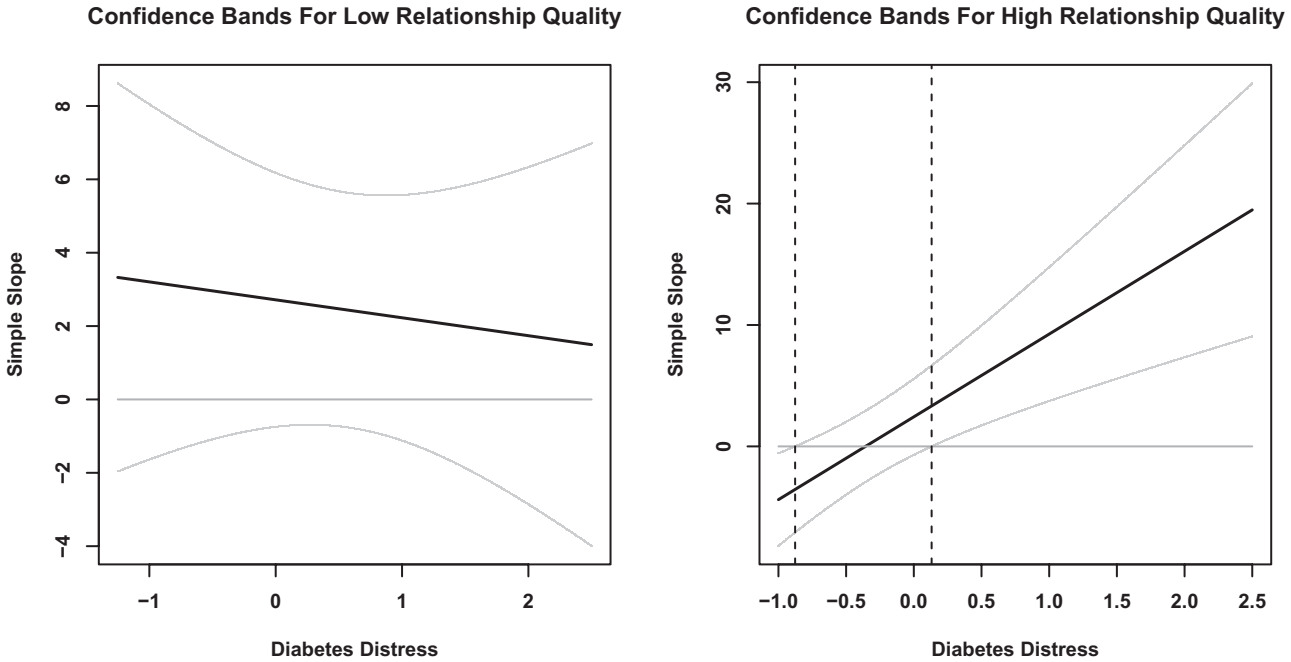

Fig. 2. Confidence bands and regions of significance for three-way interaction between spousal influence, diabetes distress, and relationship quality (all mean centered). The *y*-axis is the simple slope for spousal influence predicting glucose coefficient of variation (CV). Regions of significance are bound by vertical dashed lines. Confidence bands are shown in gray. For low relationship quality (left panel), there is no region of significance for the simple slope. For high relationship quality (right panel), the simple slopes are significant *outside* the bounded regions; that is, simple slopes are significant for diabetes distress scores below −0.877 and above 0.132.

interaction between spousal influence, diabetes distress, and relationship quality remained statistically significant. The same is true when PWD-reported, but not spouse-reported, spousal influence is included.

Discussion

This study sought to identify contextual moderators of the association between spousal influence on diabetes self-care and CGM-based metrics of glycemic control in PWD. Building on prior research on spousal influence and HbA1c in PWD [23–28], we used CGM to examine not only mean glucose level but also glucose variability, as are both uniquely predictive of downstream complications of type 2 diabetes [29, 32, 33]. We hypothesized that diabetes distress and relationship quality would moderate the effects of spousal influence on PWD's mean glucose level and glucose variability over a 7-day CGM period.

Contrary to hypotheses, none of the interactions (or main effects) among spousal influence, diabetes distress, and relationship quality significantly predicted mean glucose level during the 7-day CGM period. Although diabetes distress and mean glucose showed a strong positive univariate relationship, the main effect of distress in the larger model was not significant. This is inconsistent with prior research linking diabetes distress to HbA1c [35, 36, 52]. It is possible that low statistical power made it difficult to detect significance, particularly of interaction effects. The null interaction effects conflict with a recent study that found that high autonomy support from close others buffered the positive effect of diabetes distress on HbA1c over time [52]. However, these findings have not been replicated with CGM-based indices of glycemia (for an exception, see [53]). Although HbA1c and CGM both capture levels of glucose in the blood, HbA1c reflects average levels over a 2–3-month period, while CGM reflects average levels over a weeklong period (in this study). More longitudinal and CGM research is needed to clarify the relationship between diabetes distress and glucose level generally and in relation to spousal influence.

When turning to glucose variability, findings were largely consistent with our hypothesis. As predicted, we found that spousal influence significantly interacted with diabetes distress and relationship quality to predict glucose CV. Specifically, results revealed that among PWD reporting high distress about their diabetes and high satisfaction with their intimate relationship, spouse attempts to influence their diabetes self-care were related to significantly *worse* glycemic control (i.e., higher CV = more glucose variability). Somewhat surprisingly, higher relationship quality did *not* buffer the association between spousal influence and glucose variability overall—in fact, higher relationship satisfaction was actually associated with a larger positive slope, but only

among PWD in considerable distress. This unexpected finding highlights the need for more dyadic research to accurately model these complex interactions between intra- and interpersonal processes, particularly as they relate to clinical outcomes in diabetes care.

Overall, these results support the notion that PWD who feel overburdened and overwhelmed by their diabetes might not benefit from their spouses' direct attempts to instigate health behavior change. A key finding from this study is that more spousal influence is linked to more glucose variability among PWD with higher levels of diabetes distress. This is consistent with the idea that direct spousal influence may exacerbate the effects of distress on glucose control by reinforcing PWD's feelings of being unable to meet self-care demands on their own. As hypothesized, we also found that for PWD who are not particularly distressed about diabetes or their relationship, spousal influence was associated with *improved* glycemic control (i.e., lower CV = less glucose variability). Thus, spousal attempts to promote PWD's self-care were associated with the benefits (presumably) intended—but only among PWD who felt unburdened by diabetes and held positive global evaluations of their intimate relationship. This pattern of results is consistent with well-supported theories in relationship science, although they have been rarely applied to the behavioral medicine context [54, 55].

If replicated, these findings may be particularly applicable to the development and/or modification of diabetes interventions (e.g., educational component for spouses), as well as clinical decision-making when screening and monitoring diabetes distress [1, 56]. This would be timely and feasible given that routine clinical diabetes care increasingly involves assessing and addressing diabetes distress [57]. These results underscore the importance of assessing and treating diabetes distress in routine clinical settings by extending its relevance to matching PWD to optimal intervention approaches (e.g., individual- vs. couple-oriented interventions). However, more research is needed to understand the clinical implications of our findings. Because causality cannot be inferred from our results, it is possible that poor glycemic control leads to more diabetes distress and/or spousal influence. Experimental and longitudinal research is sorely needed to disentangle directionality of these effects. Future intervention trials should measure and examine spousal influence, diabetes distress, and relationship quality as potential treatment moderators, and take care to sample the full range of scores on these variables. It will also be important for future research to explore whether other forms (or measures) of spousal influence are associated with enhanced self-care among distressed PWD. For example, more general emotional support from spouses may indirectly benefit these PWD by buffering diabetes distress. Future work should consider whether spouses' own diabetes distress affects the helpfulness of their influence and if so, how this can be addressed in couple-focused diabetes interventions.

Several limitations of the current study are worth noting. First, although we hypothesize a causal relationship between spousal influence and glycemic control, causality cannot be inferred from this observational study. More research is needed to rule out alternative explanations, such as the reverse causal sequence (e.g., poor glycemic control may elicit or trigger spouses to attempt influence). In addition, future work should consider other potential confounds, including contextual factors such as socioeconomic status or cultural differences. Relatedly, longitudinal research is needed to determine whether the *between-person* associations found here exist at the within-person level (i.e., whether momentary shifts in spousal influence, distress, and relationship quality correspond to within-person shifts in glucose) and investigate the directionality of effects (i.e., lagged effects). Second, because a relatively small sample was used and the parent study was not specifically designed or powered to study the current research question, both the null and significant effects reported here should be considered tentative until replicated in a well-powered study. Third, this study's sample size precluded the analysis of other potential covariates or moderators, such as gender, which should be considered in future studies [24, 58]. Fourth, the representativeness of this sample is limited by only including PWD treated by an endocrinologist. It is unclear whether these findings generalize to PWD whose diabetes is adequately managed by primary care providers (indeed, the majority of type 2 diabetes cases are managed in primary care setting [59]). Furthermore, members of racial/ethnic minority groups are less likely to have access to specialty care, such as endocrinology [60], and this was reflected in the demographic composition of the current sample. Finally, most PWD in this sample were generally satisfied in their intimate relationships (just over 6% had QMI scores in the clinically significant distress). This limitation is characteristic of most studies on couples coping with illness [61], so more research is needed to understand how highly distressed couples function in this context.

Taken together, our findings are consistent with the idea that the interpersonal and emotional context within which spousal influence occurs is key to understanding its effects on disease management and health behavior. The size of the effect found for this set of predictors on glucose CV is particularly noteworthy and highlights the need for additional research—under certain conditions, a 1 *SD* increase in spousal influence predicted nearly a nine-unit increase in CV. This is roughly equivalent to

the difference between our sample mean CV (~29%) and a CV that falls in the *unstable* glycemia range. Further, this is the first study to report the association between diabetes distress and glucose variability, which is increasingly recognized as a critical indicator of overall glycemic control [32–34]. Overall, these results support the central role of the spouse's involvement in PWD self-care and potential for leveraging their influence to improve diabetes outcomes.

Funding

This study was generously funded by the United States National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK; grants R21DK098679 and F31DK120201). This study was partially supported by the Einstein–Mount Sinai Diabetes Research Center (P30 DK020541) and the New York Regional Center for Diabetes Translation Research (P30 DK111022) from the National Institutes of Health. The study sponsor was not involved in the design of the study, the collection, analysis, and interpretation of data, writing the report, or the decision to submit the report for publication.

Compliance with Ethical Standards

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards Authors Emily C. Soriano, M. James Lenhard, Jeffrey S. Gonzalez, Howard Tennen, Sy-Miin Chow, Amy K. Otto, Christine Perndorfer, Biing-Jiun Shen, Scott D. Siegel, and Jean-Philippe Laurenceau declare that they have no conflict of interest.

Authors' Contributions E.C.S. conceptualized and wrote the paper with critical input and editing from all authors as well as close mentorship from M.J.L., J.S.G., H.T., S-M.C., S.D.S., and J-P.L. J-P.L. and B-J.S. designed the parent study with input from M.J.L., S.D.S., E.C.S., and A.K.O. Data were collected by E.C.S., A.K.O., and C.P., and analyzed by E.C.S. and J-P.L. Lead author E.C.S. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Ethical Approval Informed consent was obtained from all individual participants included in the study.

Informed Consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

1. American Diabetes Association. Lifestyle management: standards of medical care in diabetes—2019. *Diabetes Care.* 2019;42(suppl 1):S46–S60.
2. Pillay J, Armstrong MJ, Butalia S, et al. Behavioral programs for type 2 diabetes mellitus: a systematic review and network meta-analysis. *Ann Intern Med.* 2015;163(11):848.
3. Terranova CO, Brakenridge CL, Lawler SP, Eakin EG, Reeves MM. Effectiveness of lifestyle-based weight loss interventions for adults with type 2 diabetes: a systematic review and meta-analysis. *Diabetes Obes Metab.* 2015;17(4):371–378.
4. NCD Risk Factor Collaboration. Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. *Lancet.* 2016;387(10027):1513–1530.
5. Liu H, Waite L, Shen S. Diabetes risk and disease management in later life: a national longitudinal study of the role of marital quality. *J Gerontol B Psychol Sci Soc Sci.* 2016;71(6):1070–1080.
6. Surwit RS, van Tilburg MAL, Zucker N, et al. Stress management improves long-term glycemic control in type 2 diabetes. *Diabetes Care*. 2002;25(1):30–34.
7. Kacerovsky-Bielesz G, Lienhardt S, Hagenhofer M, et al. Sex-related psychological effects on metabolic control in type 2 diabetes mellitus. *Diabetologia.* 2009;52(5):781–788.
8. Gazmararian JA, Ziemer DC, Barnes C. Perception of barriers to self-care management among diabetic patients. *Diabetes Educ.* 2009;35(5):778–788.
9. Novak JR, Anderson JR, Johnson MD, et al. Does personality matter in diabetes adherence? Exploring the pathways between neuroticism and patient adherence in couples with type 2 diabetes. *Appl Psychol Health Well Being.* 2017;9(2):207–227.
10. Helgeson VS, Mascatelli K, Seltman H, Korytkowski M, Hausmann LR. Implications of supportive and unsupportive behavior for couples with newly diagnosed diabetes. *Health Psychol.* 2016;35(10):1047–1058.
11. Soto SC, Louie SY, Cherrington AL, Parada H, Horton LA, Ayala GX. An ecological perspective on diabetes self-care support, self-management behaviors, and hemoglobin A1C among Latinos. *Diabetes Educ.* 2015;41(2):214–223.
12. Epple C, Wright AL, Joish VN, Bauer M. The role of active family nutritional support in Navajos' type 2 diabetes metabolic control. *Diabetes Care.* 2003;26(10):2829–2834.
13. Martire LM, Helgeson VS. Close relationships and the management of chronic illness: associations and interventions. *Am Psychol.* 2017;72(6):601–612.
14. Whisman MA, Li A, Sbarra DA, Raison CL. Marital quality and diabetes: results from the Health and Retirement Study. *Health Psychol.* 2014;33(8):832–840.
15. Trief PM, Morin PC, Izquierdo R, et al. Marital quality and diabetes outcomes: the IDEATel Project. *Fam Syst Health.* 2006;24(3):318–331.
16. Trief PM, Fisher L, Sandberg J, et al. Health and psychosocial outcomes of a telephonic couples behavior change intervention in patients with poorly controlled type 2 diabetes: a randomized clinical trial. *Diabetes Care.* 2016;39(12):2165–2173.
17. Baig AA, Benitez A, Quinn MT, Burnet DL. Family interventions to improve diabetes outcomes for adults. *Ann N Y Acad Sci.* 2015;1353(1):89–112.
18. Vongmany J, Luckett T, Lam L, Phillips JL. Family behaviours that have an impact on the self-management activities of adults living with Type 2 diabetes: a systematic review and meta-synthesis. *Diabet Med.* 2018;35(2):184–194.
19. August KJ, Sorkin DH. Marital status and gender differences in managing a chronic illness: the function of health-related social control. *Soc Sci Med.* 2010;71(10):1831–1838.
20. Khan CM, Stephens MA, Franks MM, Rook KS, Salem JK. Influences of spousal support and control on diabetes management through physical activity. *Health Psychol.* 2013;32(7):739–747.
21. Stephens MA, Franks MM, Rook KS, Iida M, Hemphill RC, Salem JK. Spouses' attempts to regulate day-to-day dietary

adherence among patients with type 2 diabetes. *Health Psychol.* 2013;32(10):1029–1037.
22. Craddock E, vanDellen MR, Novak SA, Ranby KW. Influence in relationships: a meta-analysis on health-related social control. *Basic Appl Soc Psychol*. 2015;37(2):118–130.
23. Cohen O, Birnbaum GE, Meyuchas R, Levinger Z, Florian V, Mikulincer M. Attachment orientations and spouse support in adults with type 2 diabetes. *Psychol Health Med*. 2005;10(2):161–165.
24. Grzywacz JG, Arcury TA, Saldana S, et al. Social control in older adults' diabetes self management and well-being. *Behav Med.* 2012;38(4):115–120.
25. Mayberry LS, Berg CA, Greevy RA Jr, Wallston KA. Assessing helpful and harmful family and friend involvement in adults' type 2 diabetes self-management. *Patient Educ Couns.* 2019;102(7):1380–1388.
26. Mayberry LS, Osborn CY. Family involvement is helpful and harmful to patients' self-care and glycemic control. *Patient Educ Couns.* 2014;97(3):418–425.
27. Mayberry LS, Osborn CY. Family support, medication adherence, and glycemic control among adults with type 2 diabetes. *Diabetes Care.* 2012;35(6):1239–1245.
28. David D, Dalton J, Magny-Normilus C, Brain MM, Linster T, Lee SJ. The quality of family relationships, diabetes self-care, and health outcomes in older adults. *Diabetes Spectr.* 2019;32:132–138.
29. Danne T, Nimri R, Battelino T, et al. International Consensus on Use of Continuous Glucose Monitoring. *Diabetes Care.* 2017;40(12):1631–1640.
30. Kovatchev BP. Metrics for glycaemic control—from HbA1c to continuous glucose monitoring. *Nat Rev Endocrinol.* 2017;13(7):425–436.
31. Vigersky RA, Shin J, Jiang B, Siegmund T, McMahon C, Thomas A. The comprehensive glucose pentagon: a glucose-centric composite metric for assessing glycemic control in persons with diabetes. *J Diabetes Sci Technol.* 2018;12(1):114–123.
32. DeVries JH. Glucose variability: where it is important and how to measure it. *Diabetes.* 2013;62(5):1405–1408.
33. Siegelaar SE, Holleman F, Hoekstra JB, DeVries JH. Glucose variability; does it matter? *Endocr Rev.* 2010;31(2):171–182.
34. Suh S, Kim JH. Glycemic variability: how do we measure it and why is it important? *Diabetes Metab J.* 2015;39(4):273–282.
35. Powers MA, Bardsley J, Cypress M, et al. Diabetes self-management education and support in type 2 diabetes: a joint position statement of the American Diabetes Association, the American Association of Diabetes Educators, and the Academy of Nutrition and Dietetics. *J Acad Nutr Diet.* 2015;115(8):1323–1334.
36. Fisher L, Hessler DM, Polonsky WH, Mullan J. When is diabetes distress clinically meaningful? Establishing cut points for the Diabetes Distress Scale. *Diabetes Care.* 2012;35(2):259–264.
37. Gonzalez JS, Kane NS, Binko DH, Shapira A, Hoogendoorn CJ. Tangled up in blue: unraveling the links between emotional distress and treatment adherence in type 2 diabetes. *Diabetes Care.* 2016;39(12):2182–2189.
38. Lewis MA, Butterfield RM. Antecedents and reactions to health-related social control. *Pers Soc Psychol Bull.* 2005;31(3):416–427.
39. Butterfield RM, Lewis MA. Health-related social influence: a social ecological perspective on tactic use. *J Soc Pers Relatsh.* 2002;19(4):505–526.
40. Lewis MA, Butterfield RM. Social control in marital relationships: effect of one's partner on health behaviors. *J Appl Soc Psychol.* 2007;37(2):298–319.
41. Lewis MA, Butterfield RM, Darbes LA, Johnston-Brooks C. The conceptualization and assessment of health-related social control. *J Soc Pers Relatsh.* 2004;21(5):669–687.
42. Novak SA, Webster GD. Spousal social control during a weight loss attempt: a daily diary study. *Pers Relatsh.* 2011;18(2):224–241.
43. Thorpe CT, Lewis MA, Sterba KR. Reactions to health-related social control in young adults with type 1 diabetes. *J Behav Med.* 2008;31(2):93–103.
44. Tucker JS. Health-related social control within older adults' relationships. *J Gerontol B Psychol Sci Soc Sci.* 2002;57(5):P387–P395.
45. Polonsky WH, Fisher L, Earles J, et al. Assessing psychosocial distress in diabetes: development of the diabetes distress scale. *Diabetes Care.* 2005;28(3):626–631.
46. Schmitt A, Reimer A, Kulzer B, Haak T, Ehrmann D, Hermanns N. How to assess diabetes distress: comparison of the Problem Areas in Diabetes Scale (PAID) and the Diabetes Distress Scale (DDS). *Diabet Med.* 2016;33(6):835–843.
47. Norton R. Measuring marital quality: a critical look at the dependent variable. *J Marriage Fam.* 1983;45(1):141.
48. Heyman RE, Sayers SL, Bellack AS. Global marital satisfaction versus marital adjustment: an empirical comparison of three measures. *J Fam Psychol.* 1994;8(4):15.
49. Monnier L, Colette C, Wojtusciszyn A, et al. Toward defining the threshold between low and high glucose variability in diabetes. *Diabetes Care.* 2017;40(7):832–838.
50. Muthén LK, Muthén BO. *Mplus User's Guide*. 8th ed. Los Angeles, CA: Muthén & Muthén; 1998.
51. Toobert DJ, Hampson SE, Glasgow RE. The summary of diabetes self-care activities measure: results from 7 studies and a revised scale. *Diabetes Care.* 2000;23(7):943–950.
52. Lee AA, Piette JD, Heisler M, Rosland AM. Diabetes distress and glycemic control: the buffering effect of autonomy support from important family members and friends. *Diabetes Care.* 2018;41(6):1157–1163.
53. Wagner JA, Tennen H, Feinn R, Osborn CY. Self-reported discrimination, diabetes distress, and continuous blood glucose in women with type 2 diabetes. *J Immigr Minor Health.* 2015;17(2):566–573.
54. Mikulincer M, Shaver PR. *Attachment in Adulthood: Structure, Dynamics, and Change*. 2nd ed. New York, NY: Guilford Press; 2016.
55. Lakey B, Orehek E. Relational regulation theory: a new approach to explain the link between perceived social support and mental health. *Psychol Rev.* 2011;118(3):482–495.
56. Young-Hyman D, de Groot M, Hill-Briggs F, Gonzalez JS, Hood K, Peyrot M. Psychosocial care for people with diabetes: a position statement of the American Diabetes Association. *Diabetes Care.* 2016;39(12):2126–2140.
57. Skinner TC, Joensen L, Parkin T. Twenty-five years of diabetes distress research. *Diabet Med*. 2019;dme.14157.
58. Seidel AJ, Franks MM, Stephens MA, Rook KS. Spouse control and type 2 diabetes management: moderating effects of dyadic expectations for spouse involvement. *Fam Relat.* 2012;61(4):698–709.
59. Davidson JA. The increasing role of primary care physicians in caring for patients with type 2 diabetes mellitus. *Mayo Clin Proc.* 2010;85(12 suppl):S3–S4.
60. Peek ME, Cargill A, Huang ES. Diabetes health disparities: a systematic review of health care interventions. *Med Care Res Rev.* 2007;64(5 suppl):101S–156S.
61. Hagedoorn M, Hein FL, Schulz T, et al. Are patient and relationship variables associated with participation of intimate partners in couples research? *Health Psychol.* 2015;34(3):270–273.