Parental Involvement Buffers Associations Between Pump Duration and Metabolic Control among Adolescents with Type 1 Diabetes

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Objectives To examine pump duration associations with adolescents’ metabolic control and whether parental involvement moderated this association. Methods This study used a cross-sectional sample of 10- to 14-year-olds with diabetes (N = 252, 53.6% female) and parents’ reported parental involvement; HbA1c was obtained from medical records. Half (50.8%) were on an insulin pump (continuous subcutaneous insulin infusion, CSII), with the remainder prescribed multiple daily injections (MDI). Results Adolescents on CSII displayed better HbA1c than those on MDI. A curvilinear association revealed that participants on CSII for < 2 years showed a positive pump duration-HbA1c association, while those on CSII longer showed no association. Parental involvement interacted with pump duration to predict HbA1c. Pump duration was associated with poorer HbA1c only when parents were relatively uninvolved. Conclusions Within the limitations of a cross-sectional design, data suggest that adolescents on CSII have better HbA1c than those on MDI, but may experience a period of deterioration that can be offset by parental involvement.

Key words adolescents; continuous subcutaneous insulin infusion; diabetes mellitus, type 1; insulin pump; parental involvement.

Patients with type 1 diabetes on continuous subcutaneous insulin infusion (CSII) often display better metabolic control and improved quality of life compared to their own prepump levels or to patients on multiple daily injections (MDI) (Ahern et al., 2002; Phillip, Battelino, Rodriguez, Danne, & Kaufman, 2007; Pickup & Keen, 2002; Weintrob et al., 2003; Weissberg-Benchell, Antisdel-Lomaglio, & Seshadri, 2003; Wood et al., 2006). However, adolescents appear to experience fewer glycemic benefits from CSII than do younger children or adults (Silverstein et al., 2005). For example, in studies comparing HbA1c before and after initiating CSII, adolescents show no improvements (Willi, Planton, Egede, & Schwarz, 2003), smaller improvements (Nabhan, Rardin, Meier, Eugster, & DiMeglio, 2006; Nimri et al., 2006), or initial improvements that are more likely to deteriorate over time (Kordonouri et al., 2006; Rabbone et al., 2007) compared to younger or older samples. This period of deterioration may last for several years before stabilizing at or below prepump levels (Hanas & Adolfsson, 2006; Kapellen et al., 2007; Nabhan et al., 2006; Plotnick, Clark, Brancati, & Erlinger, 2003; Rabbone et al., 2007). It is important to consider pump duration because patients are often selected for CSII after...
demonstrating high motivation and an ability to follow an intense regimen (Cogen, Streisand, & Sarin, 2002; Phillip et al., 2007), which may be difficult to sustain once the goal of initiating CSII is achieved and its novelty diminishes (Danne et al., 2008). The present study, utilized a sample of adolescents with a range of experience on CSII (pump duration .01 – 7.0 years) to examine linear and curvilinear associations between pump duration and glycemic control.

The challenges of maintaining good metabolic control when adolescents are on CSII may depend on the level of parental involvement in diabetes management. Parents often transfer responsibility for diabetes management prematurely to their adolescent and this premature transfer is associated with poorer HbA1c (Anderson, Ho, Brackett, Finkelstein, & Laffel, 1997; Palmer et al., 2009; Wysocki et al., 1996). We know little about parental involvement among adolescents on CSII. On the one hand, parents may be more involved when teens are on CSII, given heightened anxiety about the new technology, and the number and complexity of additional tasks. Weissberg-Benchell (2007) reported that pump-related tasks are mastered at later ages than other diabetes tasks, suggesting a need for sustained parental involvement among adolescents on CSII (Weissberg-Benchell, Goodman, Lomaglio, & Zebracki, 2007). On the other hand, parents may be less involved because they are less comfortable with pump technology and because the pump performs or simplifies some tasks (Cope, Morrison, & Samuels-Reid, 2008; Rabbone et al., 2007; Sullivan-Bolyai, Knaff, Tamborlane, & Grey, 2004; Weintrob et al., 2003). This may be particularly true if CSII is initiated at an older age when the process of transferring responsibility for diabetes care from parent to child has already begun. Data are limited, but parents report being less involved after children initiate CSII (Maniatis, Toig, Klingensmith, Fay-Itzkowitz, & Chase, 2001) and take less responsibility for pump tasks as years on CSII increase (Weissberg-Benchell et al., 2007). If parental involvement declines across pump duration, this may partially explain the deterioration in metabolic control that has been associated with time on pump. If parental involvement is sustained, however, this involvement may buffer the association between pump duration and poorer HbA1c.

The current article presents a secondary analysis of a large cross-sectional data set of early adolescents and their parents to examine linear and curvilinear associations of pump duration with HbA1c. We predicted a curvilinear relationship where pump duration would be associated with higher HbA1c among those with only 1 or 2 years of CSII experience (consistent with longitudinal data suggesting a period of deterioration; Kordonouri et al., 2006), but would be unrelated to HbA1c among those with longer pump duration (suggesting stabilization; Nabhan et al., 2006). We further examined whether HbA1c among adolescents on CSII was consistently lower than the average HbA1c displayed by those on MDI, even with a period of deterioration. We then examined whether pump duration was associated with parental involvement, and whether involvement buffered its associations with metabolic control. We hypothesized that parental involvement would interact with pump duration to predict HbA1c, suggesting pump duration associations with glycemic control occurred primarily when parents were less involved.

**Research Design and Methods**

**Sample**

Participants included children and adolescents with type 1 diabetes ($N=252$) and their mothers ($N=252$) and fathers ($N=188$). Child and adolescent participants are referred to as adolescents throughout, consistent with the view that adolescence encompasses the period from age 10–18 (Arnett, 2000; Petersen, 1988). Participants were recruited during routine outpatient visits to a university diabetes clinic (76%) or a community-based private practice (24%) that followed similar treatment regimens. Recruitment occurred as part of a larger longitudinal study examining parental involvement in diabetes across adolescence; the present data were drawn from the baseline assessment of this larger study. Eligibility criteria included 10- to 14-year-olds with type 1 diabetes for at least 1 year, living with mother, and able to read and write English or Spanish. Of the qualifying patients approached, 66% agreed to participate; refusals primarily involved distance, time constraints, and lack of interest in being studied. Eligible adolescents who did versus did not participate were older [12.5 vs. 11.6 years, $t(367)=6.20, p<.01$], but did not differ on gender, pump status, HbA1c, or illness duration ($p's > .20$). Participants were primarily Caucasian (94% non-Hispanic Caucasian, 4.4% Hispanic/Latino, 1.1% African-American, 0.5% Native Hawaiian/Pacific Islander) and middle class. Families reported an average Hollingshead Index of 42.04, indicating a medium business, minor professional, technical status; most (73%) reported earning $50,000 or more annually. Half (50.8%) were on CSII, with the remainder prescribed MDI. Participants on MDI reported a mean of 4.2 insulin injections and 5.0 blood glucose tests daily; 58% were on a basal bolus regimen, while 42% reported being on NPH-based regimens. Table I provides more information regarding sample characteristics.
Procedures and Measures

The study was approved by the Institutional Review Board. Parents gave written informed consent, and youth gave written assent. Following recruitment, participants received a packet of questionnaires to be completed individually prior to attending a laboratory appointment, which involved additional questionnaires and interviews.

The procedures for initiating insulin pump therapy at participating clinics required patients to demonstrate motivation to learn about the pump (e.g., attend pump training class), skills to use the pump and to follow an intense regimen (e.g., carbohydrate counting, blood glucose record keeping, ability to adjust insulin or diet for high or low blood glucose), and sufficient family support and financial resources. Clinics did not differ on HbA1c, age, sex, ethnicity, or Hollingshead Index, $p’s > .10$, but they did differ on several pump-relevant variables. The university clinic had proportionately fewer participants on CSII, 46% versus 76%, $\chi^2 = 11.50, p = .001$, and these participants had initiated CSII at an older age, $M = 10.42$ vs. 8.29 years, $t(115) = 4.66, p < .05$, and had shorter pump duration than those from private practice, $M = 24.26$ vs. 46.70 months, $t(115) = -4.85, p = .000$. Thus, type of clinic was covaried in all analyses.

Metabolic Control

HbA1c was obtained at recruitment using Bayer DCA2000 by clinic staff. The time between the HbA1c measure and questionnaires ($M = 12.42$ days) was unrelated to primary study variables (i.e., parental involvement, HbA1c, pump duration, $r = -0.05$ to $0.04$, ns).

Parental Involvement

Revised responsibility items from the Diabetes Responsibility and Conflict Scale (Rubin, Young-Hyman, & Peyrot, 1989) assessed parents’ and adolescents’ perceptions of who is responsible for 23 aspects of diabetes management. Original items were updated and several items were added by a certified diabetes educator and an adolescent on CSII to reflect current regimens and technologies. Specifically, items referring to urine testing were replaced with blood glucose testing, items about insulin were modified to be relevant to both MDI and CSII regimens [e.g., who calculates the insulin or bolus (pump) dose], an item about carbohydrate counting was added (i.e., who figures out the number of carbohydrates in meals and snacks), and five items specific to pump therapy were added (i.e., who programs the pump basal rate; who inserts the catheter; who changes pump batteries; who checks to see how much insulin is left; who refills the...
pump). For each task, participants individually reported parents’ involvement on a 5-point scale (1 = child does alone, 3 = child and parent share equally, 5 = parent does alone). Scores were averaged across items, with higher scores indicating higher involvement. Because the pump items could not be answered by those on MDI, we computed two diabetes responsibility scores (DRS), one averaging the pump only items (DRS pump scores) and a second averaging the remaining items (DRS general scores). Pump and general scores were highly correlated, $r = .70 - .71$, and had good internal consistency across reporter, $\alpha = .87$ and .90 for adolescents, .88 and .89 for mothers, and .91 and .91 for fathers.

Analysis Plan
Exploratory analyses indicated that participants on CSII did not differ from those on MDI on sex, age, or parental involvement, but they had been diagnosed longer, and had lower HbA1c (Table I). Illness duration was positively correlated with HbA1c, $r = .29$, $p < .001$, and was covaried in subsequent analyses. Age at pump start was unrelated to HbA1c, $r = -.09$, $p > .33$, but was negatively correlated with pump duration, $r = -.74$, $p < .001$, and all reports of parental involvement, $r = -.53$ to $-.68$, $p < .001$. Age at pump start was thus included as a covariate to examine independent effects of pump duration.

The primary analyses involved hierarchical regressions within the sample of adolescents on CSII to examine linear and curvilinear (quadratic) associations of pump duration with metabolic control. When pump duration effects were present, we examined whether adolescents on CSII differed from the average HbA1c displayed by MDI participants (adjusted for covariates used in the primary analyses). This allowed us to discern whether participants on CSII had consistently better HbA1c than those on MDI, even if they experienced a period of deterioration after pump start. Finally, regression analyses were conducted to examine whether parental involvement was associated with pump duration, and whether it interacted with pump duration to predict HbA1c.

1 Because early adolescents experience significant pubertal changes that may affect HbA1c, we conducted regression analyses exploring associations between physician ratings of Tanner stage (available on 76% of participants) and metabolic control. No significant linear or curvilinear associations between Tanner stage and HbA1c were found, $p$’s > .10.

Table II. Hierarchical Linear Regression Results for Linear and Curvilinear Associations Between Pump Duration and HbA1c

<table>
<thead>
<tr>
<th>Variables</th>
<th>$b$ (SE)</th>
<th>$t$</th>
<th>$p$</th>
<th>$r^2$ change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>$-2.39$ ($2.21$)</td>
<td>$-1.08$</td>
<td>.28</td>
<td></td>
</tr>
<tr>
<td>Clinic</td>
<td>$2.94$ ($2.95$)</td>
<td>$0.98$</td>
<td>.32</td>
<td></td>
</tr>
<tr>
<td>Time since diagnosis</td>
<td>$.010$ ($0.04$)</td>
<td>$2.63$</td>
<td>.01</td>
<td></td>
</tr>
<tr>
<td>Age at pump start</td>
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<td>$.75$</td>
<td>.46</td>
<td></td>
</tr>
<tr>
<td>Pump duration—linear</td>
<td>$.002$ ($0.10$)</td>
<td>$.23$</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump duration—quadratic</td>
<td>$-$.001 ($0.000$)</td>
<td>$-2.57$</td>
<td>.01</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05.

Results
Associations of Pump Duration with HbA1c
Hierarchical regression analyses initially examined linear and curvilinear associations between pump duration and HbA1c. Covariates (i.e., age at pump start, illness duration, sex, and clinic type) and the linear effect for pump duration (centered on its mean) were entered on Step 1, while the quadratic term testing curvilinear associations between pump duration and HbA1c was entered on Step 2. As reported in Table II, the linear association between pump duration and HbA1c was not significant, but a quadratic association was found, accounting for 5% of the variance in HbA1c. As shown in Figure 1, pump duration was associated with higher HbA1c among participants who had <2 years of experience with CSII, but not among those on CSII longer. Follow-up analyses were conducted to test the simple slope relationship between pump duration and HbA1c at 1, 2, 3, 4, and 5 years by running the regressions after centering pump duration at each annual interval. Pump duration was associated with higher HbA1c (i.e., poorer glycemic control) at 1 year, $b$($SE$) = .03 (.02), $t$(110) = 2.07, $p < .05$, but was unrelated to HbA1c among those on CSII for 2 years, $b$($SE$) = .02 (.01), $t$(110) = 1.39, $p > .10$, or longer. Although the slope turned negative by 3 years duration, this did not reach conventional levels of statistical significance in any comparison, $p$’s > .061. Notably, HbA1c among adolescents on CSII was consistently lower than the average HbA1c displayed by adolescents prescribed MDI; that is, the average HbA1c of 8.82% found among MDI participants was outside the 95% confidence intervals for the quadratic effect displayed in Figure 1. These cross-sectional data are consistent with longitudinal patterns in the literature suggesting that HbA1c may deteriorate for a period after experiencing the initial benefits of CSII, but then stabilizes at levels that are better than adolescents on MDI. Furthermore, these
associations were independent of illness duration, age at pump start, type of clinic, and sex.

**Associations of Pump Duration with Parental Involvement**

Similar regression analyses were conducted to examine linear and curvilinear associations of pump duration with each measure of parental involvement (i.e., parental responsibility for general and for pump tasks across reporter), after covarying sex, clinic type, time since diagnosis, and age at pump start. Although pump duration and age at pump start were strongly correlated, they independently predicted parental involvement. Across teen, mother, and father reports, those who had been on CSII longer had lower levels of parental involvement in both pump, $b = -0.02$ to $-0.027$, and general diabetes tasks, $b = -0.01$, $t's < -2.77$, $p's < .01$. Similarly, youth who were older at pump start had lower parental involvement in both pump, $b = -0.03$ to $-0.043$, and general diabetes tasks across reporter, $b = -0.01$ to $-0.021$, $t's < -8.02$, $p's < .001$. These were strong linear effects, with age at pump start and pump duration together accounting for over 40% of the variance in parental involvement. There were no curvilinear associations between pump duration and parental involvement across reporter, $p's > .09$.

**Parental Involvement as a Buffer of the Relation between Pump Duration and HbA1c**

Regression analyses examined whether parental involvement interacted with pump duration to predict HbaA1c. Pump duration and parental involvement were centered on their means and entered with covariates (i.e., age at pump start, illness duration, sex, and clinic type) on Step 1 of the regression, while the pump duration × involvement interaction was entered on Step 2. Separate analyses were conducted for parental involvement in pump and in general diabetes tasks.

Parental involvement in pump tasks interacted with pump duration to predict HbaA1c when mother, $b = -0.01$, $R^2_{change} = .04$, $t(109) = -2.25$, $p < .05$, and father reports of involvement were analyzed, $b = -0.01$, $R^2_{change} = .05$, $t(85) = -2.30$, $p < .05$, and approached significance when teen reports of involvement were analyzed, $b = -0.01$, $t(108) = -1.97$, $p = .052$. Predicted means displayed in Figure 2 were generated by completing the
regression equation using pump duration and parental involvement scores $M \pm 1SD$, as recommended by Aiken & West (1991). With this approach, low parental involvement corresponded to DRS scores where teens were primarily responsible for completing pump tasks ($M = 1.30–1.49$ across reporter), while high involvement corresponded to parents and teens sharing responsibility for pump tasks ($M = 3.58–4.00$ across reporter). Tests of simple slopes indicated pump duration was associated with poorer metabolic control when teens were independently responsible for pump tasks, $t(109) = 2.35$ and $2.02$, $p's < .05$ for mother and teen reports, respectively, and $t(85) = 2.19$, $p < .05$ for father report. In contrast, pump duration was unrelated or even negatively related to HbA1c when teens shared responsibility for pump tasks with parents, $t(109) = -2.16$, $p < .05$ for mother report, $t(85) = -1.99$, $p = .050$ father report, and $t(109) = -1.79$, $p = .075$ for child report. Similar analyses for parental involvement in general tasks revealed no significant interactions with pump duration across teen, $b = -.01$, $t(109) = -1.07$, $p > .10$, mother, $b = -.02$, $t(109) = -1.79$, $p > .05$, and father reports of involvement, $b = -.01$, $t(85) = -1.45$, $p > .15$.

**Discussion**

Adolescents appeared to benefit from pump therapy, with benefits varying as a function of pump duration and parental involvement. Most notably, pump duration was associated with higher HbA1c among adolescents who had $<2$ years experience on CSII, but was unrelated to HbA1c among those on CSII longer. Furthermore, pump duration associations with poorer metabolic control occurred when parents were relatively uninvolved in pump management tasks, but not when parents and adolescents shared responsibilities. Although participants on CSII had better metabolic control than those on MDI regardless of pump duration, data suggest that parental involvement in CSII management of diabetes is important for sustained glycemic benefits.

There are several factors that may limit parental involvement in adolescents’ CSII regimens. Parental involvement in pump tasks was lower among those with longer pump duration and who began CSII at an older age. Adolescents who initiate CSII at an older age may display lower parental involvement for a number of reasons: they are establishing independence and assuming responsibility for diabetes care at a time when their selection for CSII documents their capabilities; their increasing desire for physical privacy may make parental involvement in CSII use particularly intrusive; they are often more technically savvy than their parents; and the pump may be perceived by parent and child as reducing the need for parental involvement. Notably, it was parental involvement in pump tasks specifically, rather than in the more general aspects of diabetes care, that buffered pump duration associations. Clinical practices that target older children or adolescents and their parents to promote shared responsibility for pump management during pump initiation and in the initial years after pump start may prove useful.

Future research examining the metabolic consequences of CSII should carefully consider how pump duration may influence findings. The present findings are consistent with patterns reported in recent longitudinal studies of pediatric patients on CSII (Hanas & Adolfsson, 2006; Kapellen et al., 2007; Nabhan et al., 2006; Plotnick et al., 2003; Rabbone et al., 2007). However, a meta-analysis of studies conducted prior to 2001 suggested that metabolic benefits of CSII begin after $\sim$1 year of pump use (Weissberg-Benchell et al., 2003). Different patterns may reflect different criteria for pump therapy candidacy across time and studies. Patients have sometimes been selected for CSII due to adverse glycemic control, and display larger reductions in HbA1c when they have poorer metabolic control at pump initiation (Nimri et al., 2006). In the present sample, however, adolescents were considered for pump therapy after demonstrating high motivation and adherence. Such tight management may be difficult to sustain once the goal of pump initiation has been met. An important finding in this regard is that even CSII participants with long pump durations had lower HbA1c than those on MDI, although this comparison must be interpreted cautiously given that selection of patients for CSII therapy was not random.

There are limitations to the current findings that can guide future research. Most importantly, the secondary analysis of cross-sectional data prevents causal interpretations. Associations of metabolic control with pump duration may have reflected cohort effects where teens with longer duration experienced different pump technology and changing practice standards compared to those with shorter duration. CSII versus MDI differences may have occurred because patients who were more motivated and adherent were selected for CSII, rather than because of direct CSII benefits (Cogen et al., 2002; Nabhan et al., 2006). Similarly, parental involvement may not only promote glycemic control, but may also be a response to levels of glycemic control in transactional patterns that cannot be examined cross-sectionally. Future research to rule-out these alternative interpretations should include...
longitudinal designs where data on relevant variables are obtained both prior to and after CSII initiation; pump duration effects can then be examined via within-subject trajectories across time and compared to participants’ own pre-pump values. Attention should also be paid to identifying the most appropriate comparison condition and, if possible, to randomly assigning participants to begin CSII versus remain on MDI. It may be informative, for example, to select an MDI comparison group from among those who have demonstrated interest in and motivation for initiating CSII, but who have not yet done so (e.g., those attending pump education classes). Additional limitations are that the sample was fairly homogeneous and focused on the ages during which CSII may be less effective. Findings may not generalize to diverse populations covering a broader age range. Finally, we focused on the metabolic aspects of pump duration. Future research will benefit from considering additional medical and psychosocial parameters beyond the present focus on HbA1c.

In conclusion, although pump therapy appears to benefit adolescents with diabetes, there may be a period of deterioration in metabolic control when teens initiate CSII that can be offset when parents and teens share responsibility for pump management. Data provide empirical support for the belief that sustained parental involvement is important for fully realizing the glycemic benefits of pump therapy during early adolescence. Health care providers may draw on these and future findings to help families balance freedoms afforded by CSII initiation with the continued monitoring required for successful pump therapy. This may entail educating families on the importance of sharing responsibility for pump management, especially for teens who initiate CSII at an older age. It may be useful to help parents and youth anticipate and solve problems around potential difficulties after initiating CSII, such as those related to deterioration in HbA1c and the sharing of responsibilities for pump management tasks. Given the extended period of potential risk to glycemic control, it may also be prudent to conduct parental-involvement check-ups and booster training sessions across the initial years after pump start. CSII is an important insulin delivery system, but poses unique challenges for adolescents that require careful training and sustained parental involvement.

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References


