Continuity and Change in Glycemic Control Trajectories From Adolescence to Emerging Adulthood

Relationships with family climate and self-concept in type 1 diabetes

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OBJECTIVE — To determine developmental classes of glycemic control in young people with type 1 diabetes throughout adolescence and emerging adulthood and assess relationships with general family climate and self-concept.

RESEARCH DESIGN AND METHODS — In an eight-wave longitudinal study, 72 individuals (37 females) completed questionnaires assessing family climate (at times 1–4) and self-concept (at times 1–4 and 6). Times 1–4 covered adolescence (mean ages were 14–17 years, respectively); times 5–8 covered emerging adulthood (mean ages were 21–25 years, respectively). At each time point, patients visited their physicians to determine A1C values, and questionnaires were sent to the physicians to obtain these values. Latent class growth analysis was used to identify developmental classes of glycemic control.

RESULTS — Latent class growth analysis favored a three-class solution, consisting of optimal control ($n = 10$), moderate control ($n = 51$), and deteriorating control ($n = 11$). From time 3 on and especially during emerging adulthood, mean A1C levels were substantially different among the classes. Additional ANOVAs indicated that at times 1, 2, and 4, the optimal control class was characterized by the most optimal family climate, whereas at times 3, 4, and 6, the deteriorating control class was characterized by the lowest score on positive self-concept.

CONCLUSIONS — From late adolescence on, a multiformity of glycemic control trajectories emerged, which became more diversified throughout emerging adulthood. Family climate and self-concept in mid-to-late adolescence served as psychosocial markers of these developmental classes.

Diabetes Care **32:797–801, 2009**

Adolescence is a critical developmental stage for the establishment of lifelong health-related behaviors in individuals afflicted with a chronic illness such as type 1 diabetes (1). Because of the developmental tasks adolescents are confronted with (2), adolescence can represent a difficult time for people with diabetes, leading to a worsening of glycemic control (3). Social-structural changes in many Western nations have resulted in the delaying of psychosocial maturity until the late teens and twenties—a period called emerging adulthood (4). Emerging adulthood is a prime transitional period marked by leaving the parental home and getting a first full-time job or attending college. Additionally, emerging adults with type 1 diabetes need to integrate their illness into this new lifestyle and cope with transitioning to the adult care system (5). Consequently, emerging adulthood, in which individuals must guide their own life paths, poses new challenges to the individual with diabetes, such as the need for flexibility and self-reliance (6).

Because of this widening of opportunities for success and failure, diversity in life pathways increases, which may be reflected in the course and redirection of glycemic control in emerging adults with type 1 diabetes (6,7). Previous research convincingly demonstrated that better glycemic control in youth with type 1 diabetes was related to improved long-term health outcomes (8). Person-centered statistical approaches are uniquely suited to capture such diversification in glycemic control. Whereas variable-centered approaches focus on describing the relations among variables and assess development at the group level, person-centered approaches classify individuals into distinct classes and look for meaningful subgroups characterized by unique developmental pathways, called developmental classes. Such an approach has found widespread usage in research on aggression and substance use and can, for instance, be used as a diagnostic tool to identify individuals characterized by maladaptive development (7,9).

Previous longitudinal research on glycemic control made use of a predominantly variable-centered approach, which yielded important information about modal development of A1C values across time (10). In the present study, we relied on a prospective longitudinal design (from mid-adolescence to emerging adulthood) and used a person-centered approach to empirically define developmental classes of glycemic control. Further, we investigated how these developmental classes were related to general family climate and positive self-concept (or self-esteem), being important markers of, respectively, inter- and intra-individual psychosocial development across time (2). Research on adolescents with diabetes linking family climate and self-concept

variables to longitudinal trajectories of glycemic control is nonexistent. Several predominantly cross-sectional studies did focus on how these variables were related to levels of glycemic control. Although it is widely assumed that a general family climate that is characterized by empathic control and organization has beneficial effects on adolescents' glycemic control, research focusing on this link yielded inconclusive findings. Whereas some studies found a positive association between variables tapping into general family control and monitoring, and degree of glycemic control, other studies failed to do so (2,11). Previous research, however, did demonstrate that parental monitoring of and involvement in the medical regimen specifically was related to better glycemic control in adolescents with diabetes (12).

Second, research linking glycemic control to self-concept variables is quite scarce but yielded some preliminary support for the hypothesis that such variables are related to A1C levels, with high scores on the self-concept variables being related to lower A1C levels (13). Also, depression in adolescents with diabetes was found to relate to poorer glycemic control (14). However, with respect to the latter link, strong associations that consistently replicated across studies were lacking (rev. in 15). In summary, although a positive self-concept and a structured and organized family climate are hypothesized to function as resources for optimizing adolescents' glycemic control, consistent research evidence from a longitudinal perspective is lacking.

The present study addressed four major research questions. First, stability coefficients of glycemic control were calculated to investigate the degree to which glycemic control throughout adolescence was associated with glycemic control throughout emerging adulthood. Second, we investigated whether meaningful developmental classes of glycemic control could be empirically distinguished using a person-centered approach. Third, we examined whether emerging adulthood, as expected based on theory (4,7), would be characterized by added diversity in developmental classes of glycemic control compared with adolescence. Finally, we investigated whether the obtained developmental classes would be differentiated based on their mean scores on general family climate and positive self-concept.

RESEARCH DESIGN AND METHODS

— Participants were taken from the German Longitudinal Study on Juvenile Diabetes (2), which received full institutional review board approval. In 1991, 109 patients with type 1 diabetes were recruited from pediatric health care services offering outpatient care in two German cities, Bonn and Freiburg (88% of the families initially contacted agreed to participate). Only the Bonn subsample ($n = 72$ at time 1; $M_{age} = 13.72$; SD 1.46) was assessed eight times and, consequently, constituted the sample for the present study (37 females, 35 males). These patients came from broad socioeconomic strata, with 24% being from low-class families, 49% from middle-class families, and 27% from upper-class families. A total of 87% came from two-parent and 13% from one-parent families, and patients had on average 1.35 brothers or sisters (SD 1.18), with a range from 0 to 6. They were followed-up in 1992, 1993, 1994, 1998, 2000, 2001, and 2002 (M_{age} at time 8 = 24.94; SD 1.43), hence covering mid-to-late adolescence and emerging adulthood. Mean duration of diabetes at time 1 was 4.79 years (SD 3.78). Mean BMI scores ranged from 20.50 (SD 2.42) at time 1 to 23.44 (SD 2.87) at time 8. Participants were visited at home by research project team members at each data wave and were asked to fill out questionnaires. At the different time points, patients visited their treating physicians to determine A1C values as a criterion for glycemic control. Questionnaires were sent to the physicians to retrieve A1C values from the patients' medical records.

As in most longitudinal studies, data were missing at different time points for different participants. For the present study, 15.62% of the data were missing. To minimize the bias associated with this occasional attrition, we used the expectation maximization algorithm to impute missing data. A nonsignificant Little's (16) Missing Completely At Random test [χ^2 (376) = 35.99, NS] indicated that missing values could be reliably estimated.

Psychosocial measures

General family climate was assessed at times 1–4 using the system maintenance dimension of the Family Environment Scale (17), tapping into the degree to which family interactions are characterized by organization and control. The latter two subscales assess the importance placed on having a clear structure in family activities and responsibilities and the extent to which clear rules and procedures are used to govern family life. Reliability and validity data of the German version are provided by Schneewind (18).

Self-concept

Positive self-concept was assessed at times 1–4 and 6 with the Offer Self-Image Questionnaire (19). The scales assessing psychological self (i.e., impulse control, emotional tone, and body image) and coping self (i.e., mastery of external world, emotional health, and superior adjustment) were combined to assess general positive self-concept or self-esteem. Sample items read: "Most of the time, I am happy" and "I feel that I am able to make decisions." A study on German adolescents revealed a Cronbach's α of 0.83 for this combined scale (20).

Statistical analysis

Pearson product-moment correlation coefficients were calculated among A1C values at the different time points to assess differential stability and change in glycemic control. Latent class growth analysis (21) with M-PLUS 4.0 was used to identify developmental classes of glycemic control. Intercepts and linear slopes were estimated from times 1 through 4 and from times 5 through 8, resulting in two sequential growth curves for each developmental class (capturing development from times 1 through 4 and from times 5 through 8, respectively). Several criteria were used to decide on the number of classes. First, the Bayesian information criterion statistic for a solution with *k* classes should be lower than for a solution with *k-1* classes, suggesting that adding additional classes improves model fit. Second, classification quality was assessed by entropy (*E*), a standardized summary measure of classification accuracy based on the posterior classification probabilities. Entropy ranges from 0.00 to 1.00, with higher values indicating more accurate classification. Third, we used the bootstrapped likelihood ratio test, which provides a *P* value that can be used to determine if there is a statistically significant improvement in fit through the inclusion of an additional class. Fourth, we evaluated the substantive usefulness of the classes. Next, one-way univariate ANOVA with subsequent post hoc Tukey's honestly significant differences tests were conducted to investigate whether the classes obtained differed on family climate and self-concept.

Table 1—*Correlations among A1C values at different time points*

	2	3	4	5	6	7	8
1. A1C T1	0.67*	0.25†	0.23†	0.07	−0.01	0.22	0.03
2. A1C T2		0.43*	0.38*	0.15	−0.02	0.18	0.06
3. A1C T3			0.40*	0.30‡	0.35‡	0.25†	0.15
4. A1C T4				0.66*	0.50*	0.45*	0.46*
5. A1C T5					0.72*	0.59*	0.63*
6. A1C T6						0.63*	0.67*
7. A1C T7							0.82*
8. A1C T8							

$n = 72$. *$P < 0.001$, †$P < 0.05$, ‡$P < 0.01$.

Figure 1—*Observed mean trends for the A1C values in the three developmental classes. The y-axis contains the A1C values. T = time. ●, moderate control; ■, optimal control; ▲, deteriorating control.*

RESULTS

Continuity and change in A1C

All A1C stability coefficients are displayed in Table 1. Stability coefficients between two adjacent time points were all significant at $P < 0.001$ and ranged from 0.40 to 0.82 (from 0.40 to 0.67 at times 1–4 and from 0.63 to 0.82 at times 5–8). A1C values at times 1 and 2 were not substantially correlated with those at times 5–8, whereas A1C values at times 3 and (especially) 4 were substantially correlated with the latter.

Developmental classes of glycemic control

Latent class growth analysis conducted on the A1C values favored a three-class solution (Bayesian information criterion 1,940.84; $E = 0.99$) over a two-class solution (Bayesian information criterion 2,021.24; $E = 0.95$), with bootstrapped likelihood ratio test significant at $P < 0.001$. In the less parsimonious four-class solution, one class consisted only of two individuals. Table 2 presents all intercepts and slopes for the three-class solution. Class 1 ($n = 51$) was labeled moderate control, class 2 ($n = 10$) optimal control, and class 3 ($n = 11$) deteriorating control. Figure 1 gives an overview of the observed mean A1C values for these classes.
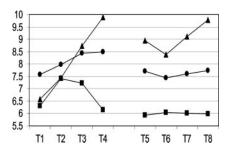
Additional χ^2 analyses indicated that males and females tended to be differently distributed among these three classes [χ^2 (2) = 4.89; $P = 0.087$], with 55, 50, and 18% of classes 1, 2, and 3, respectively, being males. Table 2 presents a series of ANOVAs, indicating that from time 3 on, significant class differences in mean A1C values emerged and that from time 5 on, all three classes were differentiated with respect to mean A1C. No substantial differences among the classes were found in (analyses not shown) adolescent family composition, socioeconomic status, mean duration of diabetes, or BMI scores across time.

Psychosocial correlates

A series of ANOVAs with developmental class as independent variable and system maintenance and self-concept as dependent variables indicated, as shown in Table 3, that the three classes differed substantially on system maintenance and self-concept at several time points. At times 1, 2, and 4, the optimal control class scored highest on system maintenance. At times 3, 4, and 6, the optimal control class scored highest and the deteriorating control class scored lowest on positive self-concept.

CONCLUSIONS

This longitudinal study is the first to examine how continued assessments of general family climate and self-concept throughout adolescence were related to differential development in glycemic control throughout adolescence and emerging adulthood. These assessments well into emerging adulthood constitute an important strength of this study because the late teens and twenties are years of profound change. Adolescents in their late teens increasingly become more independent and engage themselves in identity-related work and explorations, leading to a diversification of life paths (1,4). These developmental trends seem to be reflected in the three developmental classes of glycemic control obtained, that is, the optimal control, moderate control, and deteriorating control classes (with females being somewhat overrepresented in the third class). Indeed, from times 1–4, these classes clearly diversified with respect to mean A1C values and, as expected (4), this trend continued and further intensified throughout emerging adulthood. More specifically, whereas at times 1 and 2, the three classes were not substantially differentiated from each other with respect to A1C values, they were so from time 3 onward. In summary, these developmental classes were not only different with respect to levels (or intercepts) of A1C values, but also with respect to changes (or slopes) in A1C values throughout adolescence and emerging adulthood.

Further, we were able to isolate certain developmental factors that could partially account for these differential developmental classes of glycemic control. From time 3 on, these three classes were differentiated on the basis of their mean self-concept scores, with the optimal control class scoring the highest and the deteriorating control class scoring the

Table 2—*Intercept and slope terms for the three-class solution*

	Growth parameters			
	Times 1–4		Times 5–8	
	Mean intercept	Mean slope	Mean intercept	Mean slope
Total sample ($n = 72$)	7.54*	0.34‡	7.46*	0.08
Three classes				
Moderate control ($n = 51$)	7.80*	0.25†	7.51*	0.07
Optimal control ($n = 10$)	7.10*	−0.16	6.01*	0.01
Deteriorating control ($n = 11$)	6.47*	1.14*	8.34*	0.44*

*$P < 0.001$, †$P < 0.05$, ‡$P < 0.01$.

Table 3—*Total mean scores and univariate ANOVAs and post hoc comparisons based on Tukey's honestly significant differences tests for the three developmental classes*

| | | Developmental classes | | | | | |
	Total sample	Moderate control ($n = 51$)	Optimal control ($n = 10$)	Deteriorating control ($n = 11$)	F	P	η^2
A1C							
T1	7.40 ± 2.48	7.58 ± 2.04	6.30 ± 0.99	6.57 ± 1.62	2.78	0.069	0.07
T2	7.90 ± 2.34	7.97 ± 2.20	7.40 ± 1.94	7.45 ± 2.01	0.48	0.621	0.01
T3	8.34 ± 1.53	8.44 ± 1.15	$7.22^a \pm 2.30$	$8.74^b \pm 1.86$	3.46	0.037	0.09
T4	8.42 ± 1.90	$8.50^b \pm 1.33$	$6.16^a \pm 1.41$	$9.89^b \pm 2.64$	14.72	<0.001	0.30
T5	7.65 ± 1.16	$7.70^b \pm 0.71$	$5.94^a \pm 1.01$	$8.96^c \pm 1.17$	34.64	<0.001	0.50
T6	7.39 ± 0.85	$7.44^b \pm 0.40$	$6.03^a \pm 0.81$	$8.40^c \pm 0.90$	46.72	<0.001	0.58
T7	7.63 ± 1.06	$7.59^b \pm 0.41$	$6.01^a \pm 0.57$	$9.10^c \pm 1.21$	66.33	<0.001	0.66
T8	7.81 ± 1.14	$7.74^b \pm 0.46$	$5.98^a \pm 0.67$	$9.78^c \pm 0.33$	164.88	<0.001	0.83
Family system maintenance							
T1	53.28 ± 8.84	$51.16^a \pm 8.46$	$61.70^b \pm 6.57$	55.45 ± 7.67	7.50	0.001	0.18
T2	54.78 ± 7.57	$53.79^a \pm 6.78$	$61.10^b \pm 8.77$	$53.55^a \pm 7.89$	4.45	0.015	0.11
T3	54.33 ± 7.60	53.27 ± 7.72	59.70 ± 6.27	54.18 ± 6.79	3.14	0.050	0.08
T4	54.77 ± 7.67	$53.61^a \pm 7.66$	$61.40^b \pm 5.60$	$53.99^a \pm 7.01$	4.80	0.011	0.12
Positive self-concept							
T1	35.05 ± 5.51	35.40 ± 5.56	36.20 ± 3.61	32.36 ± 6.28	1.66	0.198	0.05
T2	32.40 ± 4.63	32.97 ± 4.31	32.60 ± 4.17	29.55 ± 5.73	2.11	0.129	0.06
T3	31.87 ± 4.93	32.27 ± 4.85	$33.20^b \pm 4.66$	$28.82^a \pm 4.73$	2.78	0.081	0.07
T4	31.81 ± 4.99	31.82 ± 4.84	$34.10^b \pm 4.79$	$29.69^a \pm 5.41$	2.60	0.069	0.07
T6	36.27 ± 4.47	36.33 ± 4.35	$38.72^b \pm 3.35$	$33.76^a \pm 4.88$	3.48	0.036	0.09

Means of the three developmental classes differ among each other if they have different superscripts. Means without superscripts do not differ from other means. T = time.

lowest on positive self-concept. As such, the present findings complement previous research (13) by demonstrating that self-concept variables are related to longitudinal trajectories of glycemic control in type 1 diabetes. Hence, these findings indicate the need to actively strengthen adolescents' self-concept to possibly yield long-term benefits in the area of glycemic control. With respect to general family climate, a somewhat different picture emerged. Although the three glycemic control classes did not have divergent A1C values at times 1 and 2, these classes were characterized by mean differences in family system maintenance (i.e., the degree of control and organization in family interactions) already at times 1 and 2. Adolescents belonging to the optimal control class experienced more family control and organization already from mid-adolescence on compared with other adolescents. Thus, adequate parental monitoring in the adolescent years seems to be beneficial to optimize glycemic control throughout adolescence and emerging adulthood (11).

The present study underscores the importance of age and developmentally appropriate diabetes education to the entire family unit for adolescents with type 1 diabetes (5). If adolescents with diabetes perceive their family climate as well organized and setting clear rules, they are more likely to follow an optimal pathway of glycemic control throughout adolescence and emerging adulthood. Adolescents whose parents provide guidance and supervision in family life have better glycemic control during adolescence and were able to maintain these levels of glycemic control during emerging adulthood. Apparently, adolescents experiencing an organized family climate seem to internalize the structure and organization that was modeled within their family and seem to apply these skills and competences to their own diabetes management later in life (22).

The differential stability observed in the A1C values throughout the study strengthens the conclusion supporting the need for a thorough diabetes education program early in adolescence (5). Stability coefficients of glycemic control were generally higher in emerging adulthood compared with adolescence, meaning that in adolescence, there seems to be more room for externally induced change in glycemic control compared with emerging adulthood. Once certain young people reach the emerging adult years and become more independent (i.e., start living on their own, find a job, and/or settle into a family of their own), it might be more difficult to change their glycemic control habits compared with when they were adolescents. In sum, the present findings underscore the need to start educating the family and the individual with diabetes already in the adolescent years to optimize the transition to independent self-care in the emerging adult years. Previous research indicated that such education may need to go hand in hand with cognitive-behavioral interventions attending to the special needs of the adolescent or emerging adult population to achieve substantial behavior change in individuals with diabetes (6).

Despite the fact that the generalizability of our findings is somewhat limited (mainly due to the modest sample size with patients all originating from a specific region of the world), the main conclusions of the present study have important implications for diabetes care. There was some degree of continuity between glycemic control status of adolescence—especially of late adolescence and not of mid-adolescence—and that of the postadolescent years (6,23). Three different developmental classes of glycemic control could be empirically identified.

A1C values diversified throughout adolescence, and this diversification was strengthened throughout emerging adulthood, as could be expected (4). Both general family climate and self-concept distinguished among these three classes from adolescence onward, with individuals in the optimal control class scoring highest on family organization and positive self-concept. Future research needs to investigate whether these classes differ with respect to treatment adherence, medical outcomes, and complications (6). Further, females were somewhat overrepresented in the deteriorating control class. Previous research indicated that adolescent girls were more distressed by their diabetes, experienced lower self-esteem, and reported more depressive and eating disorder symptoms, the latter also being associated with a less positive family climate among youth with diabetes (3,24,25). Future research should investigate whether these factors can account for the deteriorating control trajectory observed throughout adolescence and emerging adulthood for some females.

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