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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 8-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, respectively), Times 5 – 8 covered emerging adulthood (mean ages were 21 – 25, respectively). At each timepoint, patients visited their physicians to determine HbA_{1c}-values and questionnaires were sent to the physicians to obtain these values. Latent Class Growth Analysis (LCGA) was used to identify developmental classes of glycemic control.

Results – LCGA 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 HbA_{1c} levels were substantially different among the classes. Additional analyses of variance 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.

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). Due to 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 primetransitional 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).

Due to 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 HbA_{1c}-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 non-existent. 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 which 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 HbA_{1c}-levels, with high scores on the self-concept variables being related to lower HbA_{1c}-levels (13). Relatedly, 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 (for a review, see 15). In sum, 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 as compared to 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 and Procedure: 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 8 times and, consequently, constituted the sample for the present study (37 females, 35 males). These patients came from broad socio-economic strata, with 24% being from low-class, 49% from middle-class, 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 Body Mass Index (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 datawave and were asked to fill out questionnaires. At the different time-points, patients visited their treating physicians to determine HbA_{1c}-values as a criterion for glycemic control. Questionnaires were sent to the physicians to retrieve HbA_{1c}-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 was 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 ($\chi^2(376) = 35.99$, *ns*) indicated that missing values could be reliably estimated.

Psychosocial Measures: **General family climate**—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 alpha of 0.83 for this combined scale (20).

Statistical methods: Pearson product-moment correlation coefficients were calculated among HbA_{1c}-values at the different time-points to assess differential stability and change in glycemic control. Latent Class Growth Analysis (LCGA; 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 (BIC) 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 upon 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 (BLRT) 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 analyses of variance (ANOVA) with subsequent post-hoc Tukey's Honestly Significant Differences (HSD) tests were conducted to investigate whether the classes obtained differed on family climate and self-concept.

RESULTS

Continuity and Change in HbA_{1c}: All HbA_{1c} stability coefficients are displayed in Table 1. Stability coefficients between two adjacent time-points were all significant at $P < .001$ and ranged from 0.40 to 0.82 (from 0.40 to 0.67 at Times 1 through 4; and from 0.63 to 0.82 at Times 5 through 8). HbA_{1c}-values at Times 1 and 2 were not substantially correlated with those at Times 5 through 8, whereas HbA_{1c}-values at Times 3 and (especially) 4 were substantially correlated with the latter.

Developmental Classes of Glycemic Control: LCGA conducted on the HbA_{1c}-values favoured a three-class solution (BIC = 1940.84; E = 0.99) over a two-class solution (BIC = 2021.24; E = 0.95), with BLRT 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 HbA_{1c}-values for these classes.

Additional χ^2-analyses indicated that males and females tended to be differently distributed among these three classes ($\chi^2(2) = 4.89$; $P = 0.087$), 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 HbA_{1c}-values emerged, and that from Time 5 on, all three classes were differentiated with respect to mean HbA_{1c}. No substantial differences among the classes were found in (analyses not shown) adolescent family composition, socio-economic 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 to 4, these classes clearly diversified with respect to mean HbA_{1c}-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 HbA_{1c}-values, they were so from Time 3 onward. In sum, these developmental classes were not only different with respect to levels (or intercepts) of HbA_{1c}-values, but also with respect to changes (or slopes) in HbA_{1c}-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 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 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 HbA_{1c}-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 as compared to other adolescents. Thus, adequate parental monitoring in the adolescent years seems to be beneficial to optimize glycemic control thoughout 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 HbA_{1c}-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 as compared to adolescence, meaning that in adolescence there seems to be more room for externally induced change in glycemic control as compared to 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 as compared to 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 in order 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 post-adolescent years (6, 23). Three different developmental classes of glycemic control could be empirically identified. HbA_{1c}-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 onwards, 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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Table 1. *Correlations Among HbA_{1c} Values at Different Timepoints (N = 72)*

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

Note. T = Time.
$^{*}P < 0.05$. $^{**}P < 0.01$. $^{***}P < 0.001$.

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***

$^{*}P < 0.05$. $^{**}P < 0.01$. $^{***}P < 0.001$.

Table 3. *Total Mean Scores, and Univariate ANOVA's and Post-hoc Comparisons Based Upon Tukey HSD Tests for the Three Developmental Classes*

Variable	Total sample	Developmental Classes			*F*-value	*P*-value	η^2
		Moderate control (*N* = 51)	Optimal control (*N* = 10)	Deteriorating control (*N* = 11)			
HbA_{1c}							
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} ± 2.30	8.74^{b} ± 1.86	3.46	0.037	0.09
T4	8.42 ± 1.90	8.50^{b} ± 1.33	6.16^{a} ± 1.41	9.89^{b} ± 2.64	14.72	<0.001	0.30
T5	7.65 ± 1.16	7.70^{b} ± 0.71	5.94^{a} ± 1.01	8.96^{c} ± 1.17	34.64	<0.001	0.50
T6	7.39 ± 0.85	7.44^{b} ± 0.40	6.03^{a} ± 0.81	8.40^{c} ± 0.90	46.72	<0.001	0.58
T7	7.63 ± 1.06	7.59^{b} ± 0.41	6.01^{a} ± 0.57	9.10^{c} ± 1.21	66.33	<0.001	0.66
T8	7.81 ± 1.14	7.74^{b} ± 0.46	5.98^{a} ± 0.67	9.78^{c} ± 0.33	164.88	<0.001	0.83
Family system maintenan							
T1	53.28 ± 8.84	51.16^{a} ± 8.46	61.70^{b} ± 6.57	55.45 ± 7.67	7.50	0.001	0.18
T2	54.78 ± 7.57	53.79^{a} ± 6.78	61.10^{b} ± 8.77	53.55^{a} ± 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} ± 7.66	61.40^{b} ± 5.60	53.99^{a} ± 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} ± 4.66	28.82^{a} ± 4.73	2.78	0.081	0.07
T4	31.81 ± 4.99	31.82 ± 4.84	34.10^{b} ± 4.79	29.69^{a} ± 5.41	2.60	0.069	0.07
T6	36.27 ± 4.47	36.33 ± 4.35	38.72^{b} ± 3.35	33.76^{a} ± 4.88	3.48	0.036	0.09

Note. 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.

Figure 1. Observed mean trends for the HbA_{1c}-values in the three developmental classes. The Y-axis contains the HbA_{1c}-values. T = Time. Black circles = Moderate control; Black squares = Optimal control; Black triangles = Deteriorating control.