Association of individual and area-level socioeconomic conditions with quality of life and glycaemic control in 11- to 21-year-old adolescents with early-onset type 1 diabetes: a cross-sectional study (Brief Communication)

ABSTRACT

Purpose

To analyse the association of area-level deprivation (German Index of Multiple Deprivation, GIMD 2010) with health- and disease-related quality of life (QoL) and glycaemic control (HbA1c) jointly with individual-level socioeconomic status (SES) in young patients with preschool-onset type 1 diabetes.

Methods

A total of 425 male and 414 female patients aged 11 to 21 years from a Germany-wide population-based survey completed the generic KINDL-R, the DISABKIDS chronic-generic module (DCGM-12), and the DISABKIDS diabetes-specific module with impact and treatment scales (QoL indicators; range 0-100 with higher scores representing better QoL). To analyse the association of area-level deprivation and SES with QoL and HbA1c, multiple linear regression models were applied adjusting for sociodemographic and health-related variables.

Results

Mean QoL scores (SD) were 73.2 (12.2) for the KINDL-R, 76.1 (16.1) for the DCGM-12, 66.2 (19.9) for diabetes impact, and 56.4 (27.3) for diabetes treatment (DISABKIDS). Mean HbA1c was 8.3 (1.4) %. While both QoL outcomes and HbA1c level improved with increasing individual SES, no association was observed between area-level deprivation (GIMD 2010) and either outcome.

Conclusions

Compared with individual SES, area-level deprivation seems to be of minor importance for QoL and glycaemic control in young people with early-onset type 1 diabetes.

Association of individual and area-level socioeconomic conditions with quality of life and glycaemic control in 11- to 21-year-old adolescents with early-onset type 1 diabetes: a cross-sectional study (Brief Communication)

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In cooperation with the German Paediatric Surveillance Unit (ESPED) and the DPV-Science initiative, supported by the Competence Network Diabetes Mellitus

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Word count: Abstract: 199, Text: 153700; No of tables: 2; No of references: 210; No of ESM-tables 2

Acknowledgment

We thank all our participants for completing the questionnaires and the diabetes care teams throughout Germany for forwarding the questionnaires to their patients. Furthermore, we thank our colleagues at the German Diabetes Center for their faithful support during data collection and entry.

ETHICAL STATEMENTS

I. Compliance with Ethical Standards

The type 1 diabetes study was carried out in accordance with the ethical standards laid down in the Declaration of Helsinki.

II. Funding

The German Diabetes Center receives institutional funding from the German Federal Ministry of Health (BMG) and the Ministry of Science and Research of the State of North Rhine-Westphalia (MIWF NRW). The 'Clinical Course of Type 1 Diabetes in Children, Adolescents and Young Adults with Disease Onset in Preschool Age' study is a prospective study supported by grants (Grant numbers 01GI0802, 01GI1109A, 01GI0859, 01GI1106) from the Competence Network for Diabetes mellitus and the German Center for Diabetes Research (DZD, grant number 82DZD00201) (both funded by the German Federal Ministry of Education and Research [BMBF]). The current project was especially supported by a grant from the German Center for Diabetes Research (DZD). The DPV initiative (assisting in forwarding the study documents to eligible patients) is supported by the European Foundation for the Study of Diabetes (EFSD) and the Dr. Bürger-Büsing Foundation, in addition to the German Center for Diabetes Research (DZD). The funders were not involved in the study design, the data collection, the data analyses, the manuscript preparation, nor in the decision to submit the article for publication.

III. Conflicts of interest

The authors declare that they have no conflicts of interest relevant to this article.

IV. Ethical approval

The study was approved by the ethical review board at Heinrich-Heine-University Düsseldorf.

V. Informed consent

All patients and, in the case of minors, additionally their legal guardians, gave their written informed consent to participate in the study.

ABSTRACT

Purpose

To analyse the association of area-level deprivation (German Index of Multiple Deprivation, GIMD 2010) with health- and disease-related quality of life (QoL) and glycaemic control (HbA1c) jointly with individual-level socioeconomic status (SES) in young patients with preschool-onset type 1 diabetes.

Methods

A total of 425 male and 414 female patients aged 11 to 21 years from a Germany-wide population-based survey completed the generic KINDL-R, the DISABKIDS chronic-generic module (DCGM-12), and the DISABKIDS diabetes-specific module with impact and treatment scales (QoL indicators; range 0-100 with higher scores representing better QoL). To analyse the association of area-level deprivation and SES with QoL and HbA1c, multiple linear regression models were applied adjusting for sociodemographic and health-related variables.

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Mean QoL scores (SD) were 73.2 (12.2) for the KINDL-R, 76.1 (16.1) for the DCGM-12, 66.2 (19.9) for diabetes impact, and 56.4 (27.3) for diabetes treatment (DISABKIDS). Mean HbA1c was 8.3 (1.4) %. While both QoL outcomes and HbA1c level improved with increasing individual SES, no association was observed between area-level deprivation (GIMD 2010) and either outcome.

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Compared with individual SES, area-level deprivation seems to be of minor importance for QoL and glycaemic control in young people with early-onset type 1 diabetes.

KEYWORDS

Type 1 diabetes; adolescents; quality of life; HbA1c; area-level deprivation; socioeconomic status

INTRODUCTION

In the World Health Declaration 'Health21' the World Health Organization (WHO) emphasizes "*the importance of reducing social and economic inequities in improving the health of the whole population*" [1]. However, regional differences in health outcomes (e.g., type 1 diabetes-related outcomes: HbA1c, prevalence of severe hypoglycaemia or prevalence of overweight [2]) are still present and may be related to regional disparities in social, material or economic deprivation [3]. In Germany, the demographic change related to population ageing together with socioeconomic disparities lead to substantial differences in area-level deprivation which may be associated with individual health, for example mortality [4], incidence and mortality of lung and colorectal cancer [5], or type 2 diabetes prevalence [6]. A previous systematic review on health care inequalities in type 2 diabetes provided evidence that both individual and area-level social inequalities are often associated with worse diabetes outcomes [7].

A recent systematic review examined associations of individual socioeconomic status (SES) and area-level deprivation with glycaemic control, hypoglycaemia and diabetic ketoacidosis in patients with type 1 diabetes [8]. Accordingly, a lower individual SES and higher area-level deprivation were associated with an increased risk for diabetic ketoacidosis, while the results for glycaemic control and hypoglycaemia were contradictory between the included studies. However, not any of the studies analysed the influence of area-level deprivation beyond individual-level SES on diabetes outcomes. In 2014, we further reported on an association between better individual SES and QoL on the one hand and an inverse association between glycaemic control (HbA1c) and quality of life (QoL) in youths with type 1 diabetes from Germany on the other hand [9]. In another study by Galler et al. HbA1c was worse in patients with low/moderate vs. high SES [10].

Against this background of available studies, the aim of the current study was to analyse the association of area-level deprivation with health- and disease-related QoL and glycaemic control jointly with individual-level SES in patients with preschool-onset and long-term type 1 diabetes from Germany. Among patients with type 1 diabetes, this subgroup is of special interest due to its lifelong disease and the resulting increased risk of late diabetes-related complications [11,12]. We hypothesised that QoL and glycaemic control were worse in patients living in more deprived vs. less deprived areas controlling for individual SES.

MATERIALS AND METHODS

The analysis is based on data from the nationwide baseline survey (2009-2010) of the study 'Clinical Course of Type 1 Diabetes in Children, Adolescents and Young Adults with Disease Onset in Preschool Age' which was approved by the ethics committee of Heinrich Heine University Düsseldorf [13]. In short, a total of 629 children/adolescents with type 1 diabetes together with their legal guardians and 210 young adult patients with diabetes onset below 5 years between 1993 and 1999 and at least ten years diabetes duration gave their written informed consent and completed and returned comprehensive, age-adapted questionnaires (response rate 38%) [9].

For the current analyses, QoL and self-reported HbA1c (in case of minors average from children's and legal guardians' reports) were the dependent outcome variables. QoL was assessed by the well-known standardized generic Revised Children's Quality of Life Questionnaire (Kiddo-KINDL-R version, comprising six dimensions of generic health-related QoL summed up to the total score), the DISABKIDS chronic generic module (DCGM-12) and the diabetes-specific DISABKIDS diabetes module (DM impact and treatment scales) [14,15,16]. All QoL scores and subscales were transformed to a range between 0 and 100 with higher scores reflecting better QoL.

Individual-level SES and an index of area-level deprivation were considered as main independent variables. Individual SES was assessed as the total score of an established German index of social status aggregating information on the legal guardians' (in children and adolescents) or principal household earners' (in young adult patients) highest achieved educational degree, vocational qualification, and income (range 3-21, higher scores represent higher SES) [13].

The German Index of Multiple Deprivation at municipality-level for 2010 (GIMD) was used to assess area-level deprivation (range 1-74, higher scores represent increased deprivation) [17,18]. The GIMD aggregates deprivation measures from seven domains (income, education, employment, environment, municipal revenue, social capital, security, in each domain range 0-100) using data from official statistics. Each participants was assigned to a municipality with corresponding GIMD score based on the participant's residential postal code.

Age, sex, family structure (living with both biological parents or not), migration background (details are given in [13]) and an urban/rural indicator (degree of urbanization, [19]) were included as potential confounding variables. Furthermore, the following health/diabetes-related data were considered: weight status (underweight/normal weight, overweight/obesity), hospitalisations due to any cause (including diabetes) during the past 12 months (yes/no), diabetes duration, insulin therapy regimen (conventional therapy [CT, 1-3 daily injections], intensified conventional therapy [ICT, ≥4 daily injections], continuous subcutaneous insulin infusion [CSII]), and severe hypoglycaemic events during the past 12 months (last month, last 2-12 months, not at all). According to international guidelines [20], a severe hypoglycaemic event was defined as an event with altered consciousness/coma with or without seizures or an event requiring glucagon or intravenous glucose therapy.

All variables were described by means and standard deviations (SDs) or percentages (partly not shown). To analyse the association of individual-level and area-level socioeconomic conditions with QoL or HbA1c, basic multiple linear mixed regression models were applied including a random intercept related to municipalities and adjusting for the potentially confounding variables described above (Model 0). The variance partition coefficient related to the random intercept was estimated.

To investigate differences in associations of individual-level SES and area-level deprivation (GIMD) with QoL or HbA1c by sex, age group or degree of urbanization we added terms for interactions of age group (Model 1), sex (Model 2), or urbanization level (Model 3) with SES and GIMD in separate regression models. All statistical analyses were performed with SAS® version 9.4 (SAS Institute, Cary, NC, USA). P-values ≤0.05 (two-sided tests) were considered to indicate statistically significant results.

RESULTS

The study population consisted of 425 male and 414 female participants. Mean age (SD) was 16.3 (2.3) years and mean diabetes duration 13.3 (2.0) years (Table 1). Most participants used ICT (45.4%) or CSII (46.9%). Regarding QoL, the mean KINDL-R total score was 73.2 (12.2), the mean DCGM-12 score was 76.1 (16.1), and the mean values of the DISABKIDS diabetes module were 66.2 (19.9) for diabetes impact and 56.4 (27.3) for diabetes treatment, respectively. Mean HbA1c was 8.3 (1.4) % (67 [15] mmol/mol). The mean of the SES score in the cohort was 12.7 (4.3) and the mean of the GIMD was 21.1 (8.9).

According to the basic regression analyses (Model 0), both QoL outcomes and HbA1c level improved with increasing individual-level SES (for DM treatment score only by trend) (Table 2). No significant associations were observed between the GIMD and QoL indicators

or HbA1c. Associations of covariates with QoL scores or HbA1c are presented in ESM-Table 1.

Associations between SES and outcomes were not significantly different between sexes although positive associations of SES with KINDL-R, DM impact and DM treatment scores were somewhat stronger among females (ESM-Table 2, Model 1). There were weaker or no associations between SES and outcomes in pubertal adolescents (14 to 17 years) compared to the other age groups. However, significant differences in effect estimates between age-groups were indicated only for the DM treatment score and HbA1c level (ESM-Table 2, Model 2). Associations between SES and outcomes were not significantly different between levels of urbanization although there was some variation in effect estimates. SES was indicated to be positively associated with QoL scores and negatively associated with HbA1c across all urbanisation levels.

GIMD was not associated with QoL scores or HbA1c in both sexes, all age groups, and all urbanisation levels, with the one exception that GIMD was positively related to the KINDL-R score among patients living in rural areas.

In all regression models less than 10% of the variance of QoL indicators were explained by unmeasured area-level factors, and 16%-18% of the variance of HbA1c.

DISCUSSION AND CONCLUSION

To conclude, as compared with individual-level SES, area-level deprivation seems to be of minor importance for QoL and glycaemic control in young people with early-onset and long-term type 1 diabetes, in the total study group and also in both sexes, different age groups and urbanization levels of residence.

To our knowledge, this study is the first study to analyse the association of area-level deprivation with QoL and glycaemic control in type 1 diabetes jointly with individual-level

SES. Limitations of the study are the only medium-sized study cohort, low response rate, and self-report of HbA1c values. Unfortunately, we had no information regarding regional differences in health care structures and contents of diabetes care. Therefore, it cannot be ruled out that the impact of regional deprivation on QoL and HbA1c has been intercepted by engaged health care personal. Furthermore, area size and population vary widely between municipalities in Germany. Therefore, our results should be substantiated in greater future studies comprising smaller and more homogeneous area-level entities (e.g. like “super output areas” in England [21~~0~~]).

In conclusion, individual-level SES seems to be the considerably better predictor of glycaemic control and QoL in young patients with early-onset T1DM as compared to area-level deprivation. The observed associations of individual-level SES with HbA1c and QoL call for the implementation of tailored measures for socially disadvantaged patients.

TABLES

Table 1: Characteristics of study participants (N=839)

	% (n/N) or mean ± SD (N)	Median (Q1, Q3)
Male sex (%)	50.7 (425/839)	
Age (years)	16.3 ± 2.3 (839)	16.2 (14.5, 18.0)
11-13 years	18.0 (151/839)	
14-17 years	57.0 (478/839))	
18-21 years	25.0 (210/839)	
Age at onset (years)	3.0 ± 1.2 (839)	3.0 (2.0, 4.0)
Diabetes duration (years)	13.3 ± 2.0 (839)	13.2 (11.5, 15.0)
Migration background (%)	2.2 (18/837)	
Degree of urbanization		
Cities	29.9 (251/839)	
Towns/suburbs	44.2 (371/839)	
Rural areas	25.9 (217/839)	
Living not with both biological parents (%)	24.3 (203/836)	
Overweight/obesity (%)	18.8 (154/821)	
Continuous subcutaneous insulin infusion (CSII, %)	46.9 (390/831)	
Severe ~~H~~hypoglycaemic event during past 12 months (%)*	58.3 (482/827)	
Hospitalisation due to any cause (including diabetes during past 12 months (%)	26.0 (217/834)	
HbA1c (%)	8.3 ± 1.4 (798)	8.1 (7.3, 9.1)
HbA1c (mmol/mol)	67 ± 15 (798)	65 (56, 76)
Individual socioeconomic status (score)	12.7 ± 4.3 (829)	12 (9, 16)
German Index of Multiple Deprivation (GIMD, score)	21.1 ± 8.9 (839)	19.7 (14.8, 26.6)
KINDL-R (score)	73.2 ± 12.2 (824)	75.0 (66.0, 82.3)
DCGM-12 (score)	76.1 ± 16.1 (833)	79.2 (66.7, 87.5)
DM impact scale (score)	66.2 ± 19.9 (826)	70.8 (54.2, 83.3)
DM treatment scale (score)	56.4 ± 27.3 (825)	56.3 (37.5, 81.3)

Table 2: Association between individual-level socioeconomic status and area-level deprivation and quality of life scores or HbA1c (% or mmol/mol) (dependent variables): results of multiple linear mixed regression analyses

SES indicator	KINDL-R (N=791)		DISABKIDS						HbA1c (N=763)		
			DCGM-12 (N=799)		DM impact (N=794)		DM treatment (N=793)				
	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	β (95%-CI)	p-value
Individual socioeconomic status	0.281 (0.079; 0.482)	0.006	0.514 (0.249; 0.779)	<0.001	0.524 (0.196; 0.852)	0.002	0.450 (-0.015; 0.915)	0.058	-0.025 (-0.049; -0.002)	-0.276 (-0.535; -0.018)	0.036
German Index of Multiple Deprivation 2010	0.078 (-0.023; 0.178)	0.131	-0.027 (-0.157; 0.104)	0.685	-0.087 (-0.251; 0.076)	0.296	0.100 (-0.126; 0.325)	0.386	0.002 (-0.010; 0.014)	0.025 (-0.107; 0.156)	0.712
VPC	0.078		0.036		0.097		0.000		0.163		

For each outcome, estimates (regression coefficient β, 95% confidence interval [CI], p-value) are derived from a linear mixed regression model (Model 0) adjusting for sex, age, diabetes duration, family structure, migration background, degree of urbanization, insulin therapy regimen, weight status, hospitalisations due to any cause (including diabetes) during the past 12 months, and severe hypoglycaemic events during the past 12 months and including a random intercept related to municipalities.

For all independent variables, the variance inflation factor was less than 5 thus indicating no relevant multicollinearity. Further, nonparametric spline regression did not reveal any relevant non-linear components in the association of SES and GIMD 2010 with QoL indicators or HbA1c, respectively.

VPC: variance partition coefficient related to municipalities

ESM-Table 1: Association between covariates and quality of life scores or HbA1c (% or mmol/mol) (dependent variables): results of multiple linear mixed regression analyses

Covariate		KINDL-R (N=791)		DISABKIDS						HbA1c (N=763)		
				DCGM-12 (N=799)		DM impact (N=794)		DM treatment (N=793)				
		β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	β (95%-CI)	p-value
Age	per 1 year increase	-0.068 (-0.772; 0.636)	0.850	0.464 (-0.464; 1.393)	0.327	0.989 (-0.162; 2.141)	0.092	-0.303 (-1.939; 1.333)	0.716	0.073 (-0.009; 0.155)	0.796 (-0.102; 1.694)	0.082
Diabetes duration	per 1 year increase	0.003 (-0.809; 0.816)	0.993	-0.287 (-1.359; 0.786)	0.600	-0.089 (-1.418; 1.240)	0.895	0.191 (-1.694; 2.076)	0.843	-0.033 (-0.129; 0.062)	-0.365 (-1.408; 0.679)	0.493
Sex	female vs. male	-2.963 (-4.649; -1.277)	<0.001	-0.266 (-2.496; 1.964)	0.815	-1.573 (-4.324; 1.179)	0.263	-0.969 (-4.889; 2.952)	0.628	0.045 (-0.152; 0.242)	0.491 (-1.664; 2.646)	0.655
Not living with both biological parents	yes vs. no	-0.962 (-2.944; 1.020)	0.341	-1.318 (-3.926; 1.289)	0.321	-1.657 (-4.901; 1.588)	0.316	-0.378 (-4.975; 4.219)	0.872	0.226 (-0.009; 0.462)	2.474 (-0.100; 5.048)	0.060
Migration background	yes vs. no	-3.919 (-9.422; 1.583)	0.162	-3.173 (-10.495; 4.148)	0.395	-5.553 (-14.529; 3.423)	0.225	-8.580 (-21.422; 4.262)	0.190	0.207 (-0.436; 0.850)	2.266 (-4.763; 9.294)	0.527
Degree of urbanization	Cities vs. rural areas	-0.834 (-3.380; 1.714)	0.519	1.397 (-1.894; 4.687)	0.402	1.089 (-3.103; 5.281)	0.609	1.213 (-4.205; 6.632)	0.660	-0.077 (-0.383; 0.238)	-0.812 (-4.255; 2.631)	0.630
	Towns/suburbs vs. rural areas	0.993 (-1.059; 3.046)	0.342	2.106 (-0.583; 4.795)	0.125	2.076 (-1.281; 5.434)	0.225	4.007 (-0.711; 8.725)	0.096	-0.082 (-0.327; 0.162)	-0.876 (-3.543; 1.792)	0.509
Overweight / Adiposity	yes vs. no	-2.398 (-4.553; -0.243)	0.029	-3.314 (-6.144; -0.484)	0.022	-6.731 (-10.247; -3.215)	<0.001	-3.756 (-8.728; 1.216)	0.139	0.012 (-0.243; 0.266)	0.129 (-2.652; 2.910)	0.927
Insulin treatment	CT vs. pump	-0.313 (-3.495; 2.869	0.847	-3.950 (-8.163; 0.263)	0.066	-3.519 (-8.758; 1.722)	0.188	-9.211 (-16.652; -1.769)	0.015	0.157 (-0.232; 0.547)	1.720 (-2.537; 5.979)	0.428
	ICT vs. pump	0.842 (-0.877; 2.562)	0.337	-2.753 (-5.018; -0.488)	0.017	-4.403 (-7.216; -1.591)	0.002	-2.376 (-6.357; 1.605)	0.242	-0.167 (-0.369; 0.3035	-1.826 (-4.030; 0.378)	0.104
Severe ~~H~~hypoglycaemia past 12 months	1 vs. 0	-1.896 (-3.818; 0.026)	0.053	-1.442 (-3.973; 1.089)	0.264	-2.439 (-5.574; 0.696)	0.127	-3.396 (-7.851; 1.058)	0.135	0.121 (-0.105; 0.347)	1.321 (-1.146; 3.788)	0.294
	≥2 vs. 0	-3.484 (-5.586; -1.381)	0.001	-5.071 (-7.845; -2.297)	<0.001	-5.077 (-8.517; -1.637)	0.004	-7.144 (-12.029; -2.259)	0.004	0.207 (-0.039; 0.454)	2.267 (-0.422; 4.956)	0.098
Hospitalization due to any cause (including diabetes) past 12 months	yes vs. no	-2.778 (-4.682; -0.873)	0.004	-5.105 (-7.626; -2.584)	<0.001	-5.085 (-8.201; -1.970)	0.001	-4.028 (-8.464; 0.407)	0.075	0.746 (0.521; 0.971)	8.151 (5.694; 10.607)	<0.001
VPC		0.078		0.036		0.097		<0.001		0.163		

For each outcome, estimates (regression coefficient β, 95% confidence interval [CI], p-value) are derived from a linear mixed regression model (Model 0) adjusting for sex, age, diabetes duration, family structure, migration background, degree of urbanization, insulin therapy regimen, weight status, hospitalisations due to any cause (including diabetes) during the past 12 months, and severe hypoglycaemic events during the past 12 months, and including a random intercept related to municipalities. CT: conventional treatment with 1-3 injection time points; ICT: intensified conventional treatment with ≥4 injection time points; VPC: variance partition coefficient related to municipalities

ESM-Table 2: Association between individual-level socioeconomic status and area-level deprivation and quality of life scores or HbA1c (% or mmol/mol) (dependent variables) by sex, age group or degree of urbanization: results of multiple linear mixed regression analyses

Model	SES indicator	Covariate	KINDL-R (N=791)		DISABKIDS						HbA1c (N=763)		
					DCGM-12 (N=799)		DM impact (N=794)		DM treatment (N=793)		%	mmol/mol	
			β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	β (95%-CI)	p-value
Model 1	**Individual socio-economic status**	**Sex**											
		Male	0.130	0.354	0.551	0.003	0.365	0.112	0.258	0.430	-0.027	-0.290	0.114
			(-0.146; 0.406)		(0.187; 0.915)		(-0.086; 0.815)		(-0.382; 0.897)		(-0.059; 0.007)	(-0.649; 0.070)	
		Female	0.438	0.002	0.487	0.012	0.692	0.003	0.660	0.047	-0.024	-0.263	0.151
			(0.155; 0.721)		(0.106; 0.851)		(0.230; 1.154)		(0.009; 1.312)		(-0.057; 0.009)	(-0.622; 0.096)	
				0.120*		0.781*		0.310*		0.378*			0.915*
	German Index of Multiple Deprivation 2010	Male	0.071	0.322	0.022	0.819	-0.090	0.439	0.182	0.265	-0.005	-0.053	0.574
			(-0.070; 0.212)		(-0.163; 0.206)		(-0.320; 0.139)		(-0.139; 0.504)		(-0.022; 0.012)	(-0.237; 0.132)	
		Female	0.083	0.228	-0.070	0.431	-0.084	0.447	0.024	0.879	0.008	0.093	0.295
			(-0.052; 0.217)		(-0.244; 0.104)		(-0.302; 0.133)		(-0.280; 0.328)		(-0.007; 0.024)	(-0.081; 0.267)	
				0.903*		0.464*		0.970*		0.471*			0.240*
	VPC		0.081		0.035		0.095		0.000		0.159		
Model 2	**Individual socio-economic status**	**Age group**											
		11-13 years	0.484	0.039	0.726	0.021	0.668	0.084	0.894	0.105	-0.045	-0.496	0.094
			(0.024; 0.943)		(0.081; 1.178)		(-0.090; 1.427)		(-0.168; 1.974)		(-0.098; 0.008)	(-1.076; 0.084)	
		14-17 years	0.207	0.121	0.398	0.024	0.305	0.163	-0.106	0.730	0.002	-0.023	0.893
			(-0.055; 0.468)		(0.051; 0.745)		(-0.124; 0.734)		(-0.711; 0.499)		(-0.028; -0.032)	(-0.309; 0.355)	
		18-21years	0.414	0.038	0.653	0.013	0.910	0.005	1.464	0.001	-0.088	-0.964	<0.001
			(0.023; 0.802)		(0.141; 1.165)		(0.279; 1.540)		(0.577; 2.351)		(-0.134; -0.042)	(-1.468; -0.461)	
				0.480*		0.550*		0.265*		0.010*			0.004*
	German Index of Multiple Deprivation 2010	11-13 years	0.098	0.370	-0.106	0.465	-0.294	0.103	0.012	0.961	0.008	0.087	0.532
			(-0.116; 0.312)		(-0.392; 0.179)		(-0.647; -0.059)		(-0.489; 0.514)		(-0.017; 0.033)	(-0.185; 0.358)	
		14-17 years	0.028	0.676	-0.022	0.800	-0.089	0.410	0.150	0.315	0.004	0.045	0.598
			(-0.103; 0.159)		(-0.191; 0.147)		(-0.301; 0.123)		(-0.143; 0.443)		(-0.011; 0.020)	(-0.123; 0.213)	
		18-21 years	0.171	0.076	0.018	0.885	0.057	0.717	0.009	0.967	-0.007	-0.071	0.576
			(-0.018; 0.360)		(-0.230; 0.267)		(-0.252; 0.366)		(-0.423; 0.441)		(-0.029; 0.016)	(-0.320; 0.178)	
				0.439*		0.803*		0.330*		0.817*			0.649*
	VPC		0.091		0.030		0.102		<0.001		0.178		

ESM-Table 2: ***(continued)***

Model 3	**Individual socio-economic status**	**Urbanization**											
		Cities	0.237	0.172	0.499	0.030	0.457	0.105	0.329	0.412	-0.047	-0.515	0.021
			(-0.103; 0.578)		(0.048; 0.950)		(-0.096; 1.009)		(-0.456; 1.113)		(-0.087; -0.007)	(-0.951; -0.079)	
		Towns/suburbs	0.332	0.027	0.541	0.006	0.357	0.145	0.415	0.233	-0.015	-0.167	0.381
			(0.038; 0.626)		(0.154; 0.928)		(-0.123; 0.837)		(-0.268; 1.097)		(-0.050; 0.0219	(-0.541; 0.207)	
		Rural areas	0.217	0.307	0.472	0.091	0.938	0.007	0.709	0.149	-0.012	-0.134	0.630
			(-0.200; 0.633)		(-0.076; 1.019)		(0.258; 1.618)		(-0.255; 1.673)		(-0.062; 0.038)	(-0.682; 0.413)	
				0.869*		0.977*		0.370*		0.824*			0.408*
	German Index of Multiple Deprivation 2010	Cities	-0.025	0.853	-0.239	0.171	0.015	0.949	0.003	0.993	-0.003	-0.035	0.855
			(-0.298; 0.247)		(-0.587; 0.109)		(-0.437; 0.466)		(-0.552; 0.557)		(-0.038; 0.032)	(-0.417; 0.347)	
		Towns/suburbs	0.044	0.541	-0.014	0.878	-0.184	0.120	0.098	0.553	0.004	0.045	0.628
			(-0.097; 0.185)		(-0.198; 0.170)		(-0.415; 0.048)		(-0.226; 0.422)		(-0.013; 0.021)	(-0.137; 0.227)	
		Rural areas	0.174	0.047	0.049	0.659	0.003	0.981	0.151	0.438	0.003	0.032	0.781
			(0.003; 0.345)		(-0.169; 0.266)		(-0.267; 0.274)		(-0.232; 0.534)		(-0.018; 0.023)	(-0.192; 0.255)	
				0.368*		0.368*		0.524*		0.910*			0.932*
	VPC		0.088		0.021		0.103		<0.001		0.180		

For each outcome, estimates (regression coefficient β, 95% confidence interval [CI], p-value) are from a linear mixed regression models adjusting for sex, age group, diabetes duration, family structure, migration background, degree of urbanization, insulin therapy regimen, weight status, hospitalisations due to any cause (including diabetes) during the past 12 months, severe hypoglycaemic events during the past 12 months, and including a district related random intercept. The first model (Model 1) additionally included interaction terms SES by sex and GIMD by sex, the second model (Model 2) interactions terms SES by age and GIMD by age, and the third model (Model 3) interaction terms SES by degree of urbanization and GIMD by urbanization.

VPC: variance partition coefficient related to municipalities; *: p-value of test for no interaction between SES indicator and covariate (equivalently: p-value of test for no difference in association of SES indicator with outcome in covariate strata)

AVAILABILITY OF RESEARCH DATA

Due to data protection and privacy issues, data are only available from the authors upon request.

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Association of individual and area-level socioeconomic conditions with quality of life and glycaemic control in 11- to 21-year-old adolescents with early-onset type 1 diabetes: a cross-sectional study (Brief Communication)

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In cooperation with the German Paediatric Surveillance Unit (ESPED) and the DPV-Science initiative, supported by the Competence Network Diabetes Mellitus

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Word count: Abstract: 199, Text: 1537; No of tables: 2; No of references: 21; No of ESM-tables 2

Acknowledgment

We thank all our participants for completing the questionnaires and the diabetes care teams throughout Germany for forwarding the questionnaires to their patients. Furthermore, we thank our colleagues at the German Diabetes Center for their faithful support during data collection and entry.

ETHICAL STATEMENTS

I. Compliance with Ethical Standards

The type 1 diabetes study was carried out in accordance with the ethical standards laid down in the Declaration of Helsinki.

II. Funding

The German Diabetes Center receives institutional funding from the German Federal Ministry of Health (BMG) and the Ministry of Science and Research of the State of North Rhine-Westphalia (MIWF NRW). The 'Clinical Course of Type 1 Diabetes in Children, Adolescents and Young Adults with Disease Onset in Preschool Age' study is a prospective study supported by grants (Grant numbers 01GI0802, 01GI1109A, 01GI0859, 01GI1106) from the Competence Network for Diabetes mellitus and the German Center for Diabetes Research (DZD, grant number 82DZD00201) (both funded by the German Federal Ministry of Education and Research [BMBF]). The current project was especially supported by a grant from the German Center for Diabetes Research (DZD). The DPV initiative (assisting in forwarding the study documents to eligible patients) is supported by the European Foundation for the Study of Diabetes (EFSD) and the Dr. Bürger-Büsing Foundation, in addition to the German Center for Diabetes Research (DZD). The funders were not involved in the study design, the data collection, the data analyses, the manuscript preparation, nor in the decision to submit the article for publication.

III. Conflicts of interest

The authors declare that they have no conflicts of interest relevant to this article.

IV. Ethical approval

The study was approved by the ethical review board at Heinrich-Heine-University Düsseldorf.

V. Informed consent

All patients and, in the case of minors, additionally their legal guardians, gave their written informed consent to participate in the study.

ABSTRACT

Purpose

To analyse the association of area-level deprivation (German Index of Multiple Deprivation, GIMD 2010) with health- and disease-related quality of life (QoL) and glycaemic control (HbA1c) jointly with individual-level socioeconomic status (SES) in young patients with preschool-onset type 1 diabetes.

Methods

A total of 425 male and 414 female patients aged 11 to 21 years from a Germany-wide population-based survey completed the generic KINDL-R, the DISABKIDS chronic-generic module (DCGM-12), and the DISABKIDS diabetes-specific module with impact and treatment scales (QoL indicators; range 0-100 with higher scores representing better QoL). To analyse the association of area-level deprivation and SES with QoL and HbA1c, multiple linear regression models were applied adjusting for sociodemographic and health-related variables.

Results

Mean QoL scores (SD) were 73.2 (12.2) for the KINDL-R, 76.1 (16.1) for the DCGM-12, 66.2 (19.9) for diabetes impact, and 56.4 (27.3) for diabetes treatment (DISABKIDS). Mean HbA1c was 8.3 (1.4) %. While both QoL outcomes and HbA1c level improved with increasing individual SES, no association was observed between area-level deprivation (GIMD 2010) and either outcome.

Conclusions

Compared with individual SES, area-level deprivation seems to be of minor importance for QoL and glycaemic control in young people with early-onset type 1 diabetes.

KEYWORDS

Type 1 diabetes; adolescents; quality of life; HbA1c; area-level deprivation; socioeconomic status

INTRODUCTION

In the World Health Declaration 'Health21' the World Health Organization (WHO) emphasizes "*the importance of reducing social and economic inequities in improving the health of the whole population*" [1]. However, regional differences in health outcomes (e.g., type 1 diabetes-related outcomes: HbA1c, prevalence of severe hypoglycaemia or prevalence of overweight [2]) are still present and may be related to regional disparities in social, material or economic deprivation [3]. In Germany, the demographic change related to population ageing together with socioeconomic disparities lead to substantial differences in area-level deprivation which may be associated with individual health, for example mortality [4], incidence and mortality of lung and colorectal cancer [5], or type 2 diabetes prevalence [6]. A previous systematic review on health care inequalities in type 2 diabetes provided evidence that both individual and area-level social inequalities are often associated with worse diabetes outcomes [7].

A recent systematic review examined associations of individual socioeconomic status (SES) and area-level deprivation with glycaemic control, hypoglycaemia and diabetic ketoacidosis in patients with type 1 diabetes [8]. Accordingly, a lower individual SES and higher area-level deprivation were associated with an increased risk for diabetic ketoacidosis, while the results for glycaemic control and hypoglycaemia were contradictory between the included studies. However, not any of the studies analysed the influence of area-level deprivation beyond individual-level SES on diabetes outcomes. In 2014, we further reported on an association between better individual SES and QoL on the one hand and an inverse association between glycaemic control (HbA1c) and quality of life (QoL) in youths with type 1 diabetes from Germany on the other hand [9]. In another study by Galler et al. HbA1c was worse in patients with low/moderate vs. high SES [10].

Against this background of available studies, the aim of the current study was to analyse the association of area-level deprivation with health- and disease-related QoL and glycaemic control jointly with individual-level SES in patients with preschool-onset and long-term type 1 diabetes from Germany. Among patients with type 1 diabetes, this subgroup is of special interest due to its lifelong disease and the resulting increased risk of late diabetes-related complications [11,12]. We hypothesised that QoL and glycaemic control were worse in patients living in more deprived vs. less deprived areas controlling for individual SES.

MATERIALS AND METHODS

The analysis is based on data from the nationwide baseline survey (2009-2010) of the study 'Clinical Course of Type 1 Diabetes in Children, Adolescents and Young Adults with Disease Onset in Preschool Age' which was approved by the ethics committee of Heinrich Heine University Düsseldorf [13]. In short, a total of 629 children/adolescents with type 1 diabetes together with their legal guardians and 210 young adult patients with diabetes onset below 5 years between 1993 and 1999 and at least ten years diabetes duration gave their written informed consent and completed and returned comprehensive, age-adapted questionnaires (response rate 38%) [9].

For the current analyses, QoL and self-reported HbA1c (in case of minors average from children's and legal guardians' reports) were the dependent outcome variables. QoL was assessed by the well-known standardized generic Revised Children's Quality of Life Questionnaire (Kiddo-KINDL-R version, comprising six dimensions of generic health-related QoL summed up to the total score), the DISABKIDS chronic generic module (DCGM-12) and the diabetes-specific DISABKIDS diabetes module (DM impact and treatment scales) [14,15,16]. All QoL scores and subscales were transformed to a range between 0 and 100 with higher scores reflecting better QoL.

Individual-level SES and an index of area-level deprivation were considered as main independent variables. Individual SES was assessed as the total score of an established German index of social status aggregating information on the legal guardians' (in children and adolescents) or principal household earners' (in young adult patients) highest achieved educational degree, vocational qualification, and income (range 3-21, higher scores represent higher SES) [13].

The German Index of Multiple Deprivation at municipality-level for 2010 (GIMD) was used to assess area-level deprivation (range 1-74, higher scores represent increased deprivation) [17,18]. The GIMD aggregates deprivation measures from seven domains (income, education, employment, environment, municipal revenue, social capital, security, in each domain range 0-100) using data from official statistics. Each participants was assigned to a municipality with corresponding GIMD score based on the participant's residential postal code.

Age, sex, family structure (living with both biological parents or not), migration background (details are given in [13]) and an urban/rural indicator (degree of urbanization, [19]) were included as potential confounding variables. Furthermore, the following health/diabetes-related data were considered: weight status (underweight/normal weight, overweight/obesity), hospitalisations due to any cause (including diabetes) during the past 12 months (yes/no), diabetes duration, insulin therapy regimen (conventional therapy [CT, 1-3 daily injections], intensified conventional therapy [ICT, ≥4 daily injections], continuous subcutaneous insulin infusion [CSII]), and severe hypoglycaemic events during the past 12 months (last month, last 2-12 months, not at all). According to international guidelines [20], a severe hypoglycaemic event was defined as an event with altered consciousness/coma with or without seizures or an event requiring glucagon or intravenous glucose therapy.

All variables were described by means and standard deviations (SDs) or percentages (partly not shown). To analyse the association of individual-level and area-level socioeconomic conditions with QoL or HbA1c, basic multiple linear mixed regression models were applied including a random intercept related to municipalities and adjusting for the potentially confounding variables described above (Model 0). The variance partition coefficient related to the random intercept was estimated.

To investigate differences in associations of individual-level SES and area-level deprivation (GIMD) with QoL or HbA1c by sex, age group or degree of urbanization we added terms for interactions of age group (Model 1), sex (Model 2), or urbanization level (Model 3) with SES and GIMD in separate regression models. All statistical analyses were performed with SAS® version 9.4 (SAS Institute, Cary, NC, USA). P-values ≤0.05 (two-sided tests) were considered to indicate statistically significant results.

RESULTS

The study population consisted of 425 male and 414 female participants. Mean age (SD) was 16.3 (2.3) years and mean diabetes duration 13.3 (2.0) years (Table 1). Most participants used ICT (45.4%) or CSII (46.9%). Regarding QoL, the mean KINDL-R total score was 73.2 (12.2), the mean DCGM-12 score was 76.1 (16.1), and the mean values of the DISABKIDS diabetes module were 66.2 (19.9) for diabetes impact and 56.4 (27.3) for diabetes treatment, respectively. Mean HbA1c was 8.3 (1.4) % (67 [15] mmol/mol). The mean of the SES score in the cohort was 12.7 (4.3) and the mean of the GIMD was 21.1 (8.9).

According to the basic regression analyses (Model 0), both QoL outcomes and HbA1c level improved with increasing individual-level SES (for DM treatment score only by trend) (Table 2). No significant associations were observed between the GIMD and QoL indicators

or HbA1c. Associations of covariates with QoL scores or HbA1c are presented in ESM-Table 1.

Associations between SES and outcomes were not significantly different between sexes although positive associations of SES with KINDL-R, DM impact and DM treatment scores were somewhat stronger among females (ESM-Table 2, Model 1). There were weaker or no associations between SES and outcomes in pubertal adolescents (14 to 17 years) compared to the other age groups. However, significant differences in effect estimates between age-groups were indicated only for the DM treatment score and HbA1c level (ESM-Table 2, Model 2). Associations between SES and outcomes were not significantly different between levels of urbanization although there was some variation in effect estimates. SES was indicated to be positively associated with QoL scores and negatively associated with HbA1c across all urbanisation levels.

GIMD was not associated with QoL scores or HbA1c in both sexes, all age groups, and all urbanisation levels, with the one exception that GIMD was positively related to the KINDL-R score among patients living in rural areas.

In all regression models less than 10% of the variance of QoL indicators were explained by unmeasured area-level factors, and 16%-18% of the variance of HbA1c.

DISCUSSION AND CONCLUSION

To conclude, as compared with individual-level SES, area-level deprivation seems to be of minor importance for QoL and glycaemic control in young people with early-onset and long-term type 1 diabetes, in the total study group and also in both sexes, different age groups and urbanization levels of residence.

To our knowledge, this study is the first study to analyse the association of area-level deprivation with QoL and glycaemic control in type 1 diabetes jointly with individual-level

SES. Limitations of the study are the only medium-sized study cohort, low response rate, and self-report of HbA1c values. Unfortunately, we had no information regarding regional differences in health care structures and contents of diabetes care. Therefore, it cannot be ruled out that the impact of regional deprivation on QoL and HbA1c has been intercepted by engaged health care personal. Furthermore, area size and population vary widely between municipalities in Germany. Therefore, our results should be substantiated in greater future studies comprising smaller and more homogeneous area-level entities (e.g. like “super output areas” in England [21]).

In conclusion, individual-level SES seems to be the considerably better predictor of glycaemic control and QoL in young patients with early-onset T1DM as compared to area-level deprivation. The observed associations of individual-level SES with HbA1c and QoL call for the implementation of tailored measures for socially disadvantaged patients.

TABLES

Table 1: Characteristics of study participants (N=839)

	% (n/N) or mean ± SD (N)	Median (Q1, Q3)
Male sex (%)	50.7 (425/839)	
Age (years)	16.3 ± 2.3 (839)	16.2 (14.5, 18.0)
11-13 years	18.0 (151/839)	
14-17 years	57.0 (478/839))	
18-21 years	25.0 (210/839)	
Age at onset (years)	3.0 ± 1.2 (839)	3.0 (2.0, 4.0)
Diabetes duration (years)	13.3 ± 2.0 (839)	13.2 (11.5, 15.0)
Migration background (%)	2.2 (18/837)	
Degree of urbanization		
Cities	29.9 (251/839)	
Towns/suburbs	44.2 (371/839)	
Rural areas	25.9 (217/839)	
Living not with both biological parents (%)	24.3 (203/836)	
Overweight/obesity (%)	18.8 (154/821)	
Continuous subcutaneous insulin infusion (CSII, %)	46.9 (390/831)	
Severe hypoglycaemic event during past 12 months (%)*	58.3 (482/827)	
Hospitalisation due to any cause (including diabetes during past 12 months (%)	26.0 (217/834)	
HbA1c (%)	8.3 ± 1.4 (798)	8.1 (7.3, 9.1)
HbA1c (mmol/mol)	67 ± 15 (798)	65 (56, 76)
Individual socioeconomic status (score)	12.7 ± 4.3 (829)	12 (9, 16)
German Index of Multiple Deprivation (GIMD, score)	21.1 ± 8.9 (839)	19.7 (14.8, 26.6)
KINDL-R (score)	73.2 ± 12.2 (824)	75.0 (66.0, 82.3)
DCGM-12 (score)	76.1 ± 16.1 (833)	79.2 (66.7, 87.5)
DM impact scale (score)	66.2 ± 19.9 (826)	70.8 (54.2, 83.3)
DM treatment scale (score)	56.4 ± 27.3 (825)	56.3 (37.5, 81.3)

Table 2: Association between individual-level socioeconomic status and area-level deprivation and quality of life scores or HbA1c (% or mmol/mol) (dependent variables): results of multiple linear mixed regression analyses

SES indicator	KINDL-R (N=791)		DISABKIDS						HbA1c (N=763)		
			DCGM-12 (N=799)		DM impact (N=794)		DM treatment (N=793)				
	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	β (95%-CI)	p-value
Individual socioeconomic status	0.281 (0.079; 0.482)	0.006	0.514 (0.249; 0.779)	<0.001	0.524 (0.196; 0.852)	0.002	0.450 (-0.015; 0.915)	0.058	-0.025 (-0.049; -0.002)	-0.276 (-0.535; -0.018)	0.036
German Index of Multiple Deprivation 2010	0.078 (-0.023; 0.178)	0.131	-0.027 (-0.157; 0.104)	0.685	-0.087 (-0.251; 0.076)	0.296	0.100 (-0.126; 0.325)	0.386	0.002 (-0.010; 0.014)	0.025 (-0.107; 0.156)	0.712
VPC	0.078		0.036		0.097		0.000		0.163		

For each outcome, estimates (regression coefficient β, 95% confidence interval [CI], p-value) are derived from a linear mixed regression model (Model 0) adjusting for sex, age, diabetes duration, family structure, migration background, degree of urbanization, insulin therapy regimen, weight status, hospitalisations due to any cause (including diabetes) during the past 12 months, and severe hypoglycaemic events during the past 12 months and including a random intercept related to municipalities.

For all independent variables, the variance inflation factor was less than 5 thus indicating no relevant multicollinearity. Further, nonparametric spline regression did not reveal any relevant non-linear components in the association of SES and GIMD 2010 with QoL indicators or HbA1c, respectively.

VPC: variance partition coefficient related to municipalities

ESM-Table 1: Association between covariates and quality of life scores or HbA1c (% or mmol/mol) (dependent variables): results of multiple linear mixed regression analyses

Covariate		KINDL-R (N=791)		DISABKIDS						HbA1c (N=763)		
				DCGM-12 (N=799)		DM impact (N=794)		DM treatment (N=793)				
		β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	β (95%-CI)	p-value
Age	per 1 year increase	-0.068 (-0.772; 0.636)	0.850	0.464 (-0.464; 1.393)	0.327	0.989 (-0.162; 2.141)	0.092	-0.303 (-1.939; 1.333)	0.716	0.073 (-0.009; 0.155)	0.796 (-0.102; 1.694)	0.082
Diabetes duration	per 1 year increase	0.003 (-0.809; 0.816)	0.993	-0.287 (-1.359; 0.786)	0.600	-0.089 (-1.418; 1.240)	0.895	0.191 (-1.694; 2.076)	0.843	-0.033 (-0.129; 0.062)	-0.365 (-1.408; 0.679)	0.493
Sex	female vs. male	-2.963 (-4.649; -1.277)	<0.001	-0.266 (-2.496; 1.964)	0.815	-1.573 (-4.324; 1.179)	0.263	-0.969 (-4.889; 2.952)	0.628	0.045 (-0.152; 0.242)	0.491 (-1.664; 2.646)	0.655
Not living with both biological parents	yes vs. no	-0.962 (-2.944; 1.020)	0.341	-1.318 (-3.926; 1.289)	0.321	-1.657 (-4.901; 1.588)	0.316	-0.378 (-4.975; 4.219)	0.872	0.226 (-0.009; 0.462)	2.474 (-0.100; 5.048)	0.060
Migration background	yes vs. no	-3.919 (-9.422; 1.583)	0.162	-3.173 (-10.495; 4.148)	0.395	-5.553 (-14.529; 3.423)	0.225	-8.580 (-21.422; 4.262)	0.190	0.207 (-0.436; 0.850)	2.266 (-4.763; 9.294)	0.527
Degree of urbanization	Cities vs. rural areas	-0.834 (-3.380; 1.714)	0.519	1.397 (-1.894; 4.687)	0.402	1.089 (-3.103; 5.281)	0.609	1.213 (-4.205; 6.632)	0.660	-0.077 (-0.383; 0.238)	-0.812 (-4.255; 2.631)	0.630
	Towns/suburbs vs. rural areas	0.993 (-1.059; 3.046)	0.342	2.106 (-0.583; 4.795)	0.125	2.076 (-1.281; 5.434)	0.225	4.007 (-0.711; 8.725)	0.096	-0.082 (-0.327; 0.162)	-0.876 (-3.543; 1.792)	0.509
Overweight / Adiposity	yes vs. no	-2.398 (-4.553; -0.243)	0.029	-3.314 (-6.144; -0.484)	0.022	-6.731 (-10.247; -3.215)	<0.001	-3.756 (-8.728; 1.216)	0.139	0.012 (-0.243; 0.266)	0.129 (-2.652; 2.910)	0.927
Insulin treatment	CT vs. pump	-0.313 (-3.495; 2.869	0.847	-3.950 (-8.163; 0.263)	0.066	-3.519 (-8.758; 1.722)	0.188	-9.211 (-16.652; -1.769)	0.015	0.157 (-0.232; 0.547)	1.720 (-2.537; 5.979)	0.428
	ICT vs. pump	0.842 (-0.877; 2.562)	0.337	-2.753 (-5.018; -0.488)	0.017	-4.403 (-7.216; -1.591)	0.002	-2.376 (-6.357; 1.605)	0.242	-0.167 (-0.369; 0.3035	-1.826 (-4.030; 0.378)	0.104
Severe hypoglycaemia past 12 months	1 vs. 0	-1.896 (-3.818; 0.026)	0.053	-1.442 (-3.973; 1.089)	0.264	-2.439 (-5.574; 0.696)	0.127	-3.396 (-7.851; 1.058)	0.135	0.121 (-0.105; 0.347)	1.321 (-1.146; 3.788)	0.294
	≥2 vs. 0	-3.484 (-5.586; -1.381)	0.001	-5.071 (-7.845; -2.297)	<0.001	-5.077 (-8.517; -1.637)	0.004	-7.144 (-12.029; -2.259)	0.004	0.207 (-0.039; 0.454)	2.267 (-0.422; 4.956)	0.098
Hospitalization due to any cause (including diabetes) past 12 months	yes vs. no	-2.778 (-4.682; -0.873)	0.004	-5.105 (-7.626; -2.584)	<0.001	-5.085 (-8.201; -1.970)	0.001	-4.028 (-8.464; 0.407)	0.075	0.746 (0.521; 0.971)	8.151 (5.694; 10.607)	<0.001
VPC		0.078		0.036		0.097		<0.001		0.163		

For each outcome, estimates (regression coefficient β, 95% confidence interval [CI], p-value) are derived from a linear mixed regression model (Model 0) adjusting for sex, age, diabetes duration, family structure, migration background, degree of urbanization, insulin therapy regimen, weight status, hospitalisations due to any cause (including diabetes) during the past 12 months, and severe hypoglycaemic events during the past 12 months, and including a random intercept related to municipalities. CT: conventional treatment with 1-3 injection time points; ICT: intensified conventional treatment with ≥4 injection time points; VPC: variance partition coefficient related to municipalities

ESM-Table 2: Association between individual-level socioeconomic status and area-level deprivation and quality of life scores or HbA1c (% or mmol/mol) (dependent variables) by sex, age group or degree of urbanization: results of multiple linear mixed regression analyses

Model	SES indicator	Covariate	KINDL-R (N=791)		DISABKIDS						HbA1c (N=763)		
					DCGM-12 (N=799)		DM impact (N=794)		DM treatment (N=793)		%	mmol/mol	
			β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	p-value	β (95%-CI)	β (95%-CI)	p-value
Model 1	**Individual socio-economic status**	**Sex**											
		Male	0.130	0.354	0.551	0.003	0.365	0.112	0.258	0.430	-0.027	-0.290	0.114
			(-0.146; 0.406)		(0.187; 0.915)		(-0.086; 0.815)		(-0.382; 0.897)		(-0.059; 0.007)	(-0.649; 0.070)	
		Female	0.438	0.002	0.487	0.012	0.692	0.003	0.660	0.047	-0.024	-0.263	0.151
			(0.155; 0.721)		(0.106; 0.851)		(0.230; 1.154)		(0.009; 1.312)		(-0.057; 0.009)	(-0.622; 0.096)	
				0.120*		0.781*		0.310*		0.378*			0.915*
	German Index of Multiple Deprivation 2010	Male	0.071	0.322	0.022	0.819	-0.090	0.439	0.182	0.265	-0.005	-0.053	0.574
			(-0.070; 0.212)		(-0.163; 0.206)		(-0.320; 0.139)		(-0.139; 0.504)		(-0.022; 0.012)	(-0.237; 0.132)	
		Female	0.083	0.228	-0.070	0.431	-0.084	0.447	0.024	0.879	0.008	0.093	0.295
			(-0.052; 0.217)		(-0.244; 0.104)		(-0.302; 0.133)		(-0.280; 0.328)		(-0.007; 0.024)	(-0.081; 0.267)	
				0.903*		0.464*		0.970*		0.471*			0.240*
	VPC		0.081		0.035		0.095		0.000		0.159		
Model 2	**Individual socio-economic status**	**Age group**											
		11-13 years	0.484	0.039	0.726	0.021	0.668	0.084	0.894	0.105	-0.045	-0.496	0.094
			(0.024; 0.943)		(0.081; 1.178)		(-0.090; 1.427)		(-0.168; 1.974)		(-0.098; 0.008)	(-1.076; 0.084)	
		14-17 years	0.207	0.121	0.398	0.024	0.305	0.163	-0.106	0.730	0.002	-0.023	0.893
			(-0.055; 0.468)		(0.051; 0.745)		(-0.124; 0.734)		(-0.711; 0.499)		(-0.028; -0.032)	(-0.309; 0.355)	
		18-21years	0.414	0.038	0.653	0.013	0.910	0.005	1.464	0.001	-0.088	-0.964	<0.001
			(0.023; 0.802)		(0.141; 1.165)		(0.279; 1.540)		(0.577; 2.351)		(-0.134; -0.042)	(-1.468; -0.461)	
				0.480*		0.550*		0.265*		0.010*			0.004*
	German Index of Multiple Deprivation 2010	11-13 years	0.098	0.370	-0.106	0.465	-0.294	0.103	0.012	0.961	0.008	0.087	0.532
			(-0.116; 0.312)		(-0.392; 0.179)		(-0.647; -0.059)		(-0.489; 0.514)		(-0.017; 0.033)	(-0.185; 0.358)	
		14-17 years	0.028	0.676	-0.022	0.800	-0.089	0.410	0.150	0.315	0.004	0.045	0.598
			(-0.103; 0.159)		(-0.191; 0.147)		(-0.301; 0.123)		(-0.143; 0.443)		(-0.011; 0.020)	(-0.123; 0.213)	
		18-21 years	0.171	0.076	0.018	0.885	0.057	0.717	0.009	0.967	-0.007	-0.071	0.576
			(-0.018; 0.360)		(-0.230; 0.267)		(-0.252; 0.366)		(-0.423; 0.441)		(-0.029; 0.016)	(-0.320; 0.178)	
				0.439*		0.803*		0.330*		0.817*			0.649*
	VPC		0.091		0.030		0.102		<0.001		0.178		

ESM-Table 2: ***(continued)***

Model 3	**Individual socio-economic status**	**Urbanization**											
		Cities	0.237	0.172	0.499	0.030	0.457	0.105	0.329	0.412	-0.047	-0.515	0.021
			(-0.103; 0.578)		(0.048; 0.950)		(-0.096; 1.009)		(-0.456; 1.113)		(-0.087; -0.007)	(-0.951; -0.079)	
		Towns/suburbs	0.332	0.027	0.541	0.006	0.357	0.145	0.415	0.233	-0.015	-0.167	0.381
			(0.038; 0.626)		(0.154; 0.928)		(-0.123; 0.837)		(-0.268; 1.097)		(-0.050; 0.0219	(-0.541; 0.207)	
		Rural areas	0.217	0.307	0.472	0.091	0.938	0.007	0.709	0.149	-0.012	-0.134	0.630
			(-0.200; 0.633)		(-0.076; 1.019)		(0.258; 1.618)		(-0.255; 1.673)		(-0.062; 0.038)	(-0.682; 0.413)	
				0.869*		0.977*		0.370*		0.824*			0.408*
	German Index of Multiple Deprivation 2010	Cities	-0.025	0.853	-0.239	0.171	0.015	0.949	0.003	0.993	-0.003	-0.035	0.855
			(-0.298; 0.247)		(-0.587; 0.109)		(-0.437; 0.466)		(-0.552; 0.557)		(-0.038; 0.032)	(-0.417; 0.347)	
		Towns/suburbs	0.044	0.541	-0.014	0.878	-0.184	0.120	0.098	0.553	0.004	0.045	0.628
			(-0.097; 0.185)		(-0.198; 0.170)		(-0.415; 0.048)		(-0.226; 0.422)		(-0.013; 0.021)	(-0.137; 0.227)	
		Rural areas	0.174	0.047	0.049	0.659	0.003	0.981	0.151	0.438	0.003	0.032	0.781
			(0.003; 0.345)		(-0.169; 0.266)		(-0.267; 0.274)		(-0.232; 0.534)		(-0.018; 0.023)	(-0.192; 0.255)	
				0.368*		0.368*		0.524*		0.910*			0.932*
	VPC		0.088		0.021		0.103		<0.001		0.180		

For each outcome, estimates (regression coefficient β, 95% confidence interval [CI], p-value) are from a linear mixed regression models adjusting for sex, age group, diabetes duration, family structure, migration background, degree of urbanization, insulin therapy regimen, weight status, hospitalisations due to any cause (including diabetes) during the past 12 months, severe hypoglycaemic events during the past 12 months, and including a district related random intercept. The first model (Model 1) additionally included interaction terms SES by sex and GIMD by sex, the second model (Model 2) interactions terms SES by age and GIMD by age, and the third model (Model 3) interaction terms SES by degree of urbanization and GIMD by urbanization.

VPC: variance partition coefficient related to municipalities; *: p-value of test for no interaction between SES indicator and covariate (equivalently: p-value of test for no difference in association of SES indicator with outcome in covariate strata)

AVAILABILITY OF RESEARCH DATA

Due to data protection and privacy issues, data are only available from the authors upon request.

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