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Association of regional socioeconomic deprivation and rurality with global developmental delay in early childhood: Data from mandatory school entry examinations in Germany

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A R T I C L E I N F O

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A B S T R A C T

Background: From birth to young adulthood, health and development of young people are strongly linked to their living situation, including their family's socioeconomic position (SEP) and living environment. The impact of regional characteristics on development in early childhood beyond family SEP has been rarely investigated. This study aimed to identify regional predictors of global developmental delay at school entry taking family SEP into consideration.
Method: We used representative, population-based data from mandatory school entry examinations of the German federal state of Brandenburg in 2018/2019 with n=22,801 preschool children. By applying binary multilevel models, we hierarchically analyzed the effect of regional deprivation defined by the German Index of Socioeconomic Deprivation (GISD) and rurality operationalized as inverted population density of the children's school district on global developmental delay (GDD) while adjusting for family SEP (low, medium and high).
Results: Family SEP was significantly and strongly linked to GDD. Children with the highest family SEP showed a lower odds for GDD compared to a medium SEP (female: OR=4.26, male: OR=3.46) and low SEP (female: OR=16.58, male: OR=12.79). Furthermore, we discovered a smaller, but additional and independent effect of regional socioeconomic deprivation on GDD, with a higher odds for children from a more deprived school district (female: OR=1.35, male: OR=1.20). However, rurality did not show a significant link to GDD in preschool children beyond family SEP and regional deprivation.
Conclusion: Family SEP and regional deprivation are risk factors for child development and of particular interest to promote health of children in early childhood and over the life course.

1. Introduction

Health inequalities among children are a major challenge at the micro- (individual), meso- (institutional) and macro-level (societal) in contemporary times (CSDH, 2008). From birth to young adulthood, the health of young people is strongly linked to their living situation, including their family's socioeconomic position (SEP) and living environment. Family SEP is widely operationalized by parental income, education and occupation or an ensemble thereof (Mahase, 2019). Previous research consistently demonstrates the association between SEP and health in the form of a social gradient, showing that children are more or less advantaged dependent on their family SEP (Lampert et al., 2018; Lampert and Kuntz, 2019). Studies also indicate that regional characteristics contribute to health inequalities as they might provide beneficial or hazardous conditions to health (Stafford and Marmot, 2003; Voigtländer et al., 2012).

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Early childhood, understood as a life period from birth to eight years, is considered a critical time for human psychomotor development (Ben-Shlomo and Kuh, 2002; Bellman et al., 2013; WHO, 2020; Hoffmann et al., 2022). Domains of children's psychomotor development are: 1. fine and gross motor skills (e.g., eye-hand coordination, body coordination), 2. cognitive functions (e.g., mathematical, narrative abilities and logical reasoning), 3. language/communication abilities (e.g., receptive syntax and vocabulary) and 4. possibilities for social interactions (e.g., behavior problems) (Bellman et al., 2013). The degree of abilities in these domains varies by an individual pace, which can result in a lack of acquired skills compared to children of the same age and sex (Khan and Leventhal; Bellman et al., 2013). The term *global developmental delay* commonly used by clinicians encompasses children with a delay in at least two of the four domains, operationalized as a minimum of two standard deviations below age- and gender-normed means in standardized tests (Bellman et al., 2013).

Extensive evidence demonstrates that children's psychomotor delay also depends on their families' SEP. For example, children under the age of eight with socioeconomic disadvantages are more likely to have a limited vocabulary (Sansavini et al., 2021), less developed gross and fine motor functions (Arabiat et al., 2021) and a higher prevalence of behavioral problems (Teymoori et al., 2018) as compared to children from more advantaged families.

The circumstances and pathways by which SEP affects children's psychomotor development are complex. Over the last two decades, explanatory approaches from social epidemiology have increasingly considered ecosocial perspectives. For example, Krieger's ecosocial theory (2001) postulates that individual health arises from a complex interplay of individual psychosocial and biological resources and the societal structures humans are embedded into (Krieger, 2001). Thus, peoples' health is determined by both individual characteristics (e.g., age, sex, genes) and the regional conditions people live in (Dahlgren and Whitehead, 2021).

There are two types of regional characteristics that are usually expected to contribute to individual health inequalities. The first are *regional socioeconomic characteristics* based on the composition of regional populations in terms of their socioeconomic profile, often classified by a geographical index (e.g., Sweden (Strömberg et al., 2021), Germany (Kroll et al., 2017), United Kingdom (Office for Health Improvement and Disparities, 2022)). The impact of regional socioeconomic characteristics on children's health is consistently evident, with a higher regional socioeconomic deprivation contributing to poorer health outcomes (Jonsson et al., 2018; Rubin et al., 2021; Visser et al., 2021).

As a second type of regional characteristics, *urbanicity/rurality,* refers to the spatial density of the population (Statistical Office of the European Union, 2021). However, their effect on health is inconclusive, as the findings vary based on both the classification schemes that are used to define areas as rural or urban (e.g., dichotomized population density versus ordinal density) and the applied geographical scales (e.g., borough, neighborhood, municipality) (Piel et al., 2020; Statistical Office of the European Union, 2021). Still, various studies corroborate geographical differences of incidences and prevalence of certain diseases: While asthma, overweight and obesity might be less prevalent among school-aged children and adolescents in rural regions (i.e., less population density) (Joens-Matre et al., 2008; Valet et al., 2009; Johnson and Mohamadi, 2015), developmental disabilities seem to occur more frequently in rural than in urban areas (3–17 years) (Zablotsky et al., 2020). Nonetheless, some studies did not find any urban-rural difference in allergy prevalence (6–18 years) (Guner et al., 2011) or in physical inactivity (15+ years) (Moreno-Llamas et al., 2021). Further studies conclude that the association between regional deprivation and health condition differs by rurality. For instance, Kitchen et al. (2021) find the effects of regional socioeconomic deprivation on COVID-19 prevalence are being worsened in rural jurisdictions. With the focus on premature limiting long-term illness, Barnett et al. (2001) demonstrate that the effect of regional unemployment is significantly higher in urban areas compared to rural areas.

The predictive value of the above regional characteristics – that go beyond individual or family SEP - on children's development - has been rarely investigated. Thus, the aim of this study was to explore the association between the regional deprivation and rurality and developmental delay in early childhood, while adjusting for individual deprivation defined as family SEP.

2. Methods

2.1. Data of school entry examinations (SEE)

We analyzed an anonymized dataset of SEE developmental outcomes of all children in the federal state of Brandenburg, Germany. The SEE is a mandatory screening of abilities relevant for school entry, which is conducted by all regional departments of public health. Law regulates the participation in the SEE before starting school for all children of school age and for all possible primary educational pathways (i.e., in elementary schools, in special needs schools (BbgSchulG, 2002)). The present investigation, therefore, is based on an unselected, population-based non-clinical sample comprising exhaustive data on children's test scores. The investigated SEE data were collected in 2018 and 2019 among children aged 5–6.5 years ($n = 22{,}801$). The data set was provided by the State Office for Occupational Safety, Consumer Protection and Health of the federal state of Brandenburg (LAVG) in consideration of national data protection requirements. An ethical approval was not applicable according to German ethical guidelines as the authors used already available, anonymized data.

The SEE in the federal state of Brandenburg consists of standardized diagnostics of children's developmental status. Trained medical staff routinely evaluates different domains of psychomotor development (motor abilities, cognitive functions, language) by using the social-pediatric screening (SOPESS) (Petermann, 2009). For our outcome "global developmental delay" (GDD), children's development is assessed in the dimensions *language* and *cognitive abilities*. The assessment of speech and language (Daseking et al., 2009) according to SOPESS refers to prepositions, plural formation and articulation of words. The child's cognitive abilities in logical reasoning (e.g., recognizing rules, thinking by analogy) are measured by using coloured progressive matrices (Petermann and Macha, 2005). In both dimensions, answers are scored, with less than 50% correct scores indicating a delayed ability in each domain (Ministry of Labor, Social Affairs, Health, Women and Family of the federal state of Brandenburg, 2020).

As the validity of the SOPESS has been proven, it serves as a gold standard for SEE: the cognitive and language domains capture developmental delays with a high specificity, and show a predictive value for later academic competencies (Daseking et al., 2009; Waldmann et al., 2009; Stich et al., 2018; Hoffmann et al., 2021).

2.1.1. Family socioeconomic position (individual deprivation)

As part of the SEE, data on paternal and maternal primary education (three-point scale: 1 no graduation/< 10th grade; 2 10th grade; 3 > 10th grade) and their employment status (dichotomous: 1 not employed; 2 half-time or full-time employed) are collected as indicators of the socioeconomic situation of each child (Brandenburg Social Index (Böhm et al., 2007)). To calculate a composite family SEP variable (SEP index), points per parent are summed, resulting in a range of index values from 4 to 10. Finally, each child is assigned to a category of "high" (9–10 points), "middle" (7–8 points) or "low" SEP (4–6 points). This additively formed index is routinely used in SEE in federal states of Germany (e.g., in Saxony-Anhalt (Pediatric and Adolescent Medical Service Saxony-Anhalt, 2018)) and is part of the public social reporting of socioeconomic inequalities in health of the federal state of Brandenburg (Böhm et al., 2007).

2.2. Regional characteristics

The SEE data were linked to regional deprivation and rurality based on all schools' official municipality identification numbers in the federal state of Brandenburg in Eastern Germany. Brandenburg is one of the largest German federal states characterized by low population density, few agglomeration centers and many agricultural and nature protection areas (Brandenburg State Center for Civic Education, 2020). Compared to other German federal states, Brandenburg's districts are predominantly disadvantaged in terms of their regional socioeconomic deprivation (Lampert et al., 2019). Brandenburg as a rural and deprived region encompasses the urban region of Berlin, the capital of Germany. For further information, the supplemental material offers a map of Germany marking the location of the federal state of Brandenburg.

2.2.1. Regional deprivation

We ranked the regional deprivation of the municipality based on The German Index of Socioeconomic Deprivation (GISD), which is a composite index of regional socioeconomic indicators in the domains of income, education and occupation. The GISD is developed by the Robert Koch Institute (Kroll et al., 2017) based on indicators for spatial development provided by the Federal Institute for Building, Urban and Spatial Research (2022). The indicators used for the GISD were: share of employees without professional qualification, share of employees with university degree, employment-to-population ratio, gross wages and salaries, net household income, share of school dropouts, private debtors per 100 inhabitants and income tax revenue per capita. The GISD values range between 0 and 1, with higher values indicating higher regional socioeconomic deprivation. We used GISD data for the year 2015.

2.2.2. Rurality

Based on recommendations of the European Statistical Commission (Statistical Office of the European Union, 2021), we operationalized "rurality" as the spatial density of the population. In order to calculate the population density of each municipality, we divided inhabitants by area size (km^2) and recoded the results to represent rurality (0-inhabitants/km^2). Higher rurality values, therefore, demonstrate less densely populated municipalities in our study. This standardization enables comparable measures of children's development among municipalities that differ by number of inhabitants and area size. By doing this, we applied the official statistics of the federal state of Brandenburg of the population (as of 31th December 2018) and of territory use (as of 31th December 2015). The data of territory use are operationalized by the municipality area that includes diverse building types (e.g., residential, public, commercial), operating areas (e.g., dump), recreational areas (e.g., sports facilities, green spaces), traffic areas (e.g., streets and railways) as well as forest or agriculture (Statistics Berlin Brandenburg, 2019). As a consequence of considering these different criteria in the operationalization of areas, we defined rurality, rather than urbanicity, as a spatial category. The advantages of such an operationalization are twofold: First, in line with data published by the German Federal Office for Building and Regional Planning, we define regions based on factors of landscape, culture, and social activity (Federal Institute for Building, Urban and Spatial Research, 2022). By doing this, we consider regional determinants in health beyond the mere number of inhabitants (e.g., physical environment: compensation, recreation and production sites) that might contribute to inequalities in health (Schmitz-Veltin, 2006; Schneider and Holzwarth, 2021). Second, we are able to capture rurality in a way that is internationally harmonized in that population density is calculated without adding it to a dichotomous variable (Statistical Office of the European Union, 2021). Hence, our explanatory variable is relevant for the description of rural German regions and is internationally comparable.

2.3. Statistical analyses

All analyses were performed using R (version 4.0.2 2020). All tests were performed stratified by gender, two-sided and considered to be statistically significant at $p < .05$. In a first step, regional deprivation and rurality were compared between children with and without diagnoses in global developmental delay (GDD) via t-tests. Secondly, we set up six (M0-M5) binary multilevel models to predict GDD as the dependent variable, in which we considered differences of predictor variables on both within-level (Level 1: individual data) and between-level (Level 2: cluster-specific data of "municipality"):

Global Developmental Delay (GDD) $_{i,n} = \beta i$ ***indexss** $_{i,n} + \beta n$ ***rur** $_{i,n} + \beta n$ ***depr** $_{i,n}$ **i** individual (Level 1) **n** municipality (Level 2).

This enables the investigation of regional deprivation and rurality as predictors of GDD, while adjusting for family deprivation (SEP) and accounting for clustered data (variable "municipality").

Using ANOVA, we investigated differences in the model fit:

- model 0 (level 2: municipality)
- model 1 (level 1: regional deprivation; level 2: municipality)
- model 2 (level 1: rurality; level 2: municipality)
- model 3 (level 1: SEP; level 2: municipality)
- model 4 (level 1: regional deprivation, rurality, SEP; level 2: municipality)
- model 5 (level 1: regional deprivation, rurality, SEP, deprivation × rurality interaction; level 2: municipality).

Model fit was assessed and compared based on the Akaike information criterion (Wagenmakers and Farrell, 2004).

Due to insufficient convergence in our models, we z-standardized deprivation and rurality (Enders and Tofighi, 2007) for the regression models and used the optimizer nlminb for all estimations (Nash, 2014). This optimization method fixes the described convergence problems that easily arise with large sample sizes due to strict thresholds in the used glmer function (Bolker, 2015) by using a quasi-Newton-method that allows bound constraints (Fox et al., 1978). For the z-standardization of rurality, we added a constant value in order to obtain positive values (2651+(0-inhabitants/km^2)).

Furthermore, we repeated model 4 without regional deprivation to investigate the predictive value of rurality without the consideration of regional deprivation. In order to repeat model 4 without highly deprived regions to examine the linearity of the effect, we calculated the quintiles of the GISD-scores and excluded all data from the 5th quintile (highest quintile of regional deprivation). Thereby, we investigated the predictive values of low and medium regional deprivation on GDD.

Testing for multicollinearity, we found no evidence for significant multicollinearity with variance inflation factors (VIF) below 1.1 for all predictors (SEP, regional deprivation, rurality). Furthermore, for all predictors the average VIF was <1.1 and tolerance statistics were >0.95 (Bowerman and O'Connell, 1990; Menard, 2002).

3. Results

Sample characteristics of $n = 22{,}801$ analyzed data points (47.61% female, 52.39% male) are displayed in Table 1. In total, the SEE data comprised $n = 315$ municipalities of schools with 32 data points on average.

Table 2 displays quintiles of regional deprivation and rurality for the subsample of children with GDD diagnosis (female: $n = 526$; male: $n = 985$).

Table 3 shows the prevalence of GDD among females, males and for the overall sample as well as mean deprivation and rurality comparing children with and without a diagnosis. Among children with GDD, the regional socioeconomic deprivation was significantly higher and rurality was significantly higher (all $p < .001$).

Model 0 in Table 4 shows 13% (female) and 8% (male) explained

Table 1
Sample characteristics (n = 22,801).

	Female	Male	Overall
% (N)	47.61 (10,856)	52.39 (11,945)	22,801
Age, M ± SD in yrs	5.86 (0.33)	5.87 (0.34)	5.87 (0.33)
Regional Deprivation, Rurality			
DEP, M ± SD	.58 (0.09)	.58 (0.09)	.58 (0.09)
Rurality, M ± SD	−371 (−398.26)	−367 (−392.30)	−369 (−395.15)
	% (N)	**% (N)**	**% (N)**
Maternal employment status			
Employed	77,79 (8,445)	76.58 (9,148)	77.16 (17,593)
Missing	8.31 (902)	9.21 (1,100)	8.78 (2,002)
Paternal employment status			
Employed	83.32 (9,045)	82.60 (9,866)	82.94 (18,911)
Missing	8.31 (902)	9.21 (1,100)	8.78 (2,002)
Maternal education			
<10 years	5.21 (556)	5.01 (599)	5.07 (1,155)
10 years	47.31 (5,136)	46.09 (5,506)	46.67 (10,642)
Abitur/University	38.03 (4,129)	38.39 (4,586)	38.22 (8,715)
Missing	9.53 (1,035)	10.50 (1,254)	10.04 (2,289)
Paternal education			
<10 years	6,49 (705)	6.21 (742)	6.35 (1,447)
10 years	53,25 (5,781)	52.52 (6,273)	52.87 (12,054)
Abitur/University	30.72 (3,335)	30.77 (3,676)	30.75 (7,011)
Missing	9.53 (1,035)	10.50 (1,2549)	10.04 (2,289)
Family Socioeconomic Position			
Low	8.17 (887)	7.79 (930)	7.97 (1,817)
Medium	39.89 (4,331)	38.97 (4,655)	39.41 (8,986)
High	41.89 (4,548)	42.08 (5,027)	41.99 (9,575)
Missing	10.04 (1,090)	11.16 (1,333)	10.63 (2,423)

Note: M = mean, SD = standard deviation, DEP = regional deprivation.

variance (ICC) by "municipality", suggesting significant variation of interest for further multilevel analyses.

3.1. Regional deprivation

Regional deprivation was significantly associated with GDD in models 1, 4 and 5. Higher scores of regional deprivation, therefore, were linked to an increased risk of GDD among both girls and boys.

3.2. Rurality

Rurality was significantly associated with GDD in model 2 only among boys. Model 4 revealed no predictive value of rurality. A repetition of model 4 without the predictor regional deprivation revealed again no predictive value of rurality (female OR = 1.00, CI95 = 0.85–1.19, $p = .976$; male OR = 1.03, CI95 = 0.90–1.17, $p = .705$).

3.3. Individual deprivation (family SEP)

Individual deprivation (family SEP) was significantly associated with GDD in models 3–5 for girls and boys (all $p < .001$). For both genders, GDD was more prevalent among children with medium and low SEP as compared to those with high family SEP (female: OR = 16.58, CI95 = 11.90–23.09 and OR = 4.26, CI95 = 3.14–5.79; male OR = 12.79, CI95 = 10.13–16.16 and OR = 3.46, CI95 = 2.83–4.22). Model 3 showed a significantly better model fit compared to model 0 ($p < .001$).

Model 4 explained 27% (girls) and 23% (boys) of variance in GDD. A repetition of model 4 without the highest quintile of regional deprivation maintained the effect of regional deprivation in the female subsample (OR = 1.55, CI95 = 1.23–1.96, $p < .001$) and a marginal effect in the male subsample (OR = 1.17, CI95 = 0.97–1.41, $p = .096$). Model 4 revealed an additional predictive value of regional deprivation (female OR = 1.35, CI95 = 1.13–1.62, $p < .001$; male OR = 1.20, CI95 = 1.05–1.39, $p < .01$) but no effect of rurality. Likewise, the model fit significantly improved from model 3 to model 4 ($p < .01$ in girls, $p < .05$ in boys).

Model 5 showed no significant interaction of rurality and regional deprivation and consequently did not show an improved model fit compared to model 4.

4. Discussion

The present study investigated the association between regional deprivation and rurality and Global Developmental Delay (GDD) among preschool children beyond the influence of individual deprivation. Analyses were based on anonymized data from school entry examinations in the federal state of Brandenburg, Germany. In an unadjusted comparison, we found that male and female children with GDD on average reside in municipalities with higher regional deprivation and higher rurality.

4.1. Regional deprivation

Multilevel analyses showed that the effect of regional deprivation sustained the adjustment of individual deprivation (family SEP) for both sexes. In line with previous findings on childrens' health and development outcomes, we found a highly significant and large effect of family SEP on language and cognitive abilities, with a higher prevalence of GDD in lower socioeconomic positions (Chen, 2014; Khanam and Nghiem, 2016).

By analyzing the effects of both regional and individual deprivation, we found an additional adverse effect of regional deprivation beyond the effect of the individual SEP. This association sustained sensitivity analyses and was also visible after the exclusion of the most deprived quintile. We can, therefore, conclude that difficulties in children's development are associated not only with a less advantaged individual socioeconomic situation but also with the socioeconomic circumstances of the area they live in. These results extend previous findings on an adverse effect of regional deprivation on physical health after accounting for individual SEP (Meijer et al., 2012). The mechanisms discussed in the literature comprise the impact that an area's inhabitants have on each other's health-related norms and values, the physical environment and the availability of health and prevention services (Diez Roux and Mair, 2010; Meijer et al., 2012). These assumptions are also in line with ecosocial perspectives as described above, as they emphasize the importance of societal processes in determining health inequalities (Krieger, 2008). Additionally, our findings are in line with research on obesity among preschool children that used SEE data from an urban area in the federal state of North Rhine Westphalia (Germany). The authors reported higher prevalence rates among children living in neighborhoods with higher regional deprivation (Nguyen et al., 2021). However, the effect of individual deprivation was significantly stronger in the present study compared to the effect of regional deprivation. This finding corresponds with literature indicating smaller effects of area characteristics on health compared to individual SEP (Stafford and Marmot, 2003).

Existing theories about the pathways by which regions affect individual health emphasized the importance of both social structures (e.g., societal education, employment, income) and contextual resources and burdens (e.g., social capital, air pollution, food supply, physical environment, labor market availability) to which interacting processes are inherent. For example, gentrification or residential segregation contribute to the extent of beneficial regional circumstances (Krieger, 2001; Voigtländer et al., 2012).

Table 2
Children with Diagnosis of Global Developmental Delay and their Regional Distribution with Reference to the Federal State of Brandenburg (Rurality and regional Deprivation).

Female (n = 526)	n by DEP Q1 - low deprivation	n by DEP Q2	n by DEP Q3	n by DEP Q4	n by DEP Q5 - high deprivation	n by RUR	% by RUR
n by RUR Q1 high density	18	6	7	33	33	97	18
n by RUR Q2	4	21	29	32	28	114	21
n by RUR Q3	8	23	16	19	27	93	18
n by RUR Q4	8	15	32	43	12	110	21
n by RUR Q5 low density	5	17	30	54	6	112	21
n by DEP	43	82	114	181	106	526	
% by DEP	8	15	21	34	20		
Male (n=983)							
n by RUR Q1 high density	53	9	6	0	56	124	13
n by RUR Q2	4	51	37	108	56	256	26
n by RUR Q3	30	52	33	40	56	211	21
n by RUR Q4	16	29	51	66	24	186	19
n by RUR Q5 low density	7	31	61	91	16	206	21
n by DEP	110	172	188	305	208	983	
% by DEP	11	17	19	31	21		

Note: Q1-Q5 = quintiles, DEP = regional deprivation (the higher the more deprived), RUR = rurality (the higher population density per km2 the more rural); n = sample size.

Table 3
Characteristics of regional deprivation and rurality by global developmental delay.

	Female (N = 10,856)		p	Male (N = 11,945)		p	Overall (N = 22,801)		p
	with GDD	without GDD		with GDD	without GDD		with GDD	without GDD	
% (N)	4.8 (526)	95.2 (10,330)		8.2 (985)	91.8 (10,960)		6.6 (1,511)	93.4 (21,290)	
Deprivation, mean	0.6084	0.5776	***	0.6020	0.5775	***	0.6042	0.5775	***
Rurality, mean	−319	−373	***	−315	−371	***	−316	−372	***

Note: $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; Deprivation = higher scores indicate higher deprivation; GDD = Global Developmental Delay; Rurality = higher scores indicate higher rurality.

4.2. Rurality

In the present study, rurality only appeared as a significant risk factor for GDD when analyses did not account for individual and regional deprivation. This supports the hypothesis that the effect of rurality on health outcomes arises from differences in both the individual situation, in particular the SEP, and the regional deprivation. Thus, it can be assumed that the composition of a population forms in part the region's social structure – e.g., the region's socioeconomic status – that, in turn, affects health outcomes above and beyond population density (Voigtländer et al., 2012).

Our findings are in line with studies suggesting no differences in prevalence rates by rurality as the effects of rurality did not affect GDD (Guner et al., 2011). However, a different geographical scale (e.g., neighborhood) or a different operationalization of rurality (e.g., population size at place of residence) might lead to different results for the association of GDD and rurality. The geographical scale of the present data (i.e., municipality) might lead to a misestimation of GDD prevalence rates and we can only conclude that rurality defined as population density of the childrens' school district did not show an association to GDD. For example, in contrast to our findings, Zablotsky et al. suggest differences in parent-reported lifetime prevalence of developmental disabilities (e.g., language, hearing problems, behavior problems, intellectual disability) among 3–17 year old children and adolescents with operationalizing urbanicity of residence by population size (Zablotsky et al., 2020). However, there are limitations to the comparability of these findings, as Zlablotsky et al. did not consider regional or individual deprivation.

The geographical scale of the present data refer to municipalities in the German federal state of Brandenburg that encompasses the German capital of Berlin (see map in the supplemental material). By this account, the regional structure of Brandenburg is dominated by the distance to Berlin and distinguishes between the „German capital Berlin surrounding areas" (including the main town of Brandenburg: Potsdam), the "Other Metropolitan areas" (e.g., Cottbus), few agglomeration areas and otherwise predominantly rural sparsely populated areas (Statistics Berlin Brandenburg, 2022). We, therefore, consider further spatial agglomeration or cluster effects to be weaker than the "Berlin effect". Nevertheless, to extend the scope of the research questions discussed in our paper, further research should take cluster analyses for assessing spatial risk clusters and neighborhood effects of municipalities into account.

5. Limitations

We were only able to use deprivation scores for the school municipalities, which might differ from the actual regional deprivation of the children's home. However, since this seems to oversimplify our models,

Table 4
Individual Socioeconomic Position, Regional Deprivation, Rurality and their Link to Global Developmental Delay (M0-M5).

		Female (N = 9,755)	Male (N = 10,605)
Model 0:	Community	ICC = 0.13	ICC = 0.08
	Marginal/Conditional R^2	0.000/0.135	0.000/0.83
		AIC = 3403.1	AIC = 5548.5
Model 1:	Deprivation	OR = 1.66***(1.42–1.94)	OR = 1.48***(1.32–1.67)
	Marginal/Conditional R^2	0.067/0.144	0.043/0.092
		AIC = 3371.7[1]	AIC = 5516.4[1]
		ICC = 0.08	ICC = 0.05
Model 2:	Rurality	OR = 1.16 (0.98–1.37)	OR = 1.16* (1.02–1.32)
	Marginal/Conditional R^2	0.006/0.132	0.006/0.082
		AIC = 3402.9	AIC = 5546.4[5]
		ICC = 0.13	ICC = 0.08
Model 3:	SEP Index [medium]	OR = 4.26*** (3.14–5.79)	OR = 3.46*** (2.83–4.22)
	SEP Index [low]	OR = 16.58*** (11.90–23.09)	OR = 12.79*** (10.13–16.16)
	Marginal/Conditional R^2	0.188/0.267	0.155/0.222
		AIC = 3083.5[1, 2, 3]	AIC = 5070.4[1, 2, 3]
		ICC = 0.10	ICC = 0.08
Model 4:	SEP Index [medium]	OR = 4.19*** (3.09–5.68)	OR = 3.39*** (2.77–4.15)
	SEP Index [low]	OR = 15.20*** (10.90–21.19)	OR = 12.13*** (9.57–15.37)
	Rurality	OR = 0.94 (0.79–1.12)	OR = 0.98 (0.86–1.12)
	Deprivation	OR = 1.35*** (1.13–1.62)	OR = 1.20** (1.05–1.39)
	Marginal/Conditional R^2	0.209/0.273	0.165/0.225
		AIC = 3076.5[1, 2, 3, 4]	AIC = 5067.8[1, 2, 3, 6]
		ICC = 0.08	ICC = 0.07
Model 5:	SEP Index [medium]	OR = 4.18*** (3.08–5.67)	OR = 3.39*** (2.77–4.14)
	SEP Index [low]	OR = 15.15*** (10.86–21.13)	OR = 12.12*** (9.56–15.37)
	Rurality	OR = 0.98 (0.80–1.20)	OR = 0.99 (0.84–1.18)
	Deprivation	OR = 1.35*** (1.13–1.61)	OR = 1.20* (1.04–1.39)
	Deprivation*Rurality	OR = 1.06 (0.88–1.26)	OR = 1.02 (0.87–1.18)
	Marginal/Conditional R^2	0.208/0.271	0.165/0.224
		AIC = 3078.1[1, 2, 3, 4]	AIC = 5069.7[1, 2, 3]
		ICC = 0.08	ICC = 0.07

Note: OR = Odds Ratio with 95% confidence intervals in brackets, ICC= Intra Class Correlation.
AIC = Akaike Information Criterion, $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$, Rurality = higher scores indicate higher rurality, Deprivation = higher scores indicate higher deprivation.
[1] = significantly better fit than model 0 p < .001.
[2] = significantly better fit than model 1 $p < .001$.
[3] = significantly better fit than model 2 $p < .001$.
[4] = significantly better fit than model 3 $p < .01$.
[5] = significantly better fit than model 0 p < .05.
[6] = significantly better fit than model 3 p < .05.

it is rather likely that our data underestimates the actual effect of regional deprivation.

As in all spatial studies, there is the risk of spatial fallacies in our analysis. In particular, the definition of regional socioeconomic deprivation of the children by school district might be too simplistic or even wrong. However, in the federal state of Brandenburg the children ordinarily have to attend the primary school responsible for their home area or habitual residence (BbgSchulG, 2002). Therefore, the spatial characterization by school district might even better describe the living environment of the children than the specific home address. A strength of our analysis is the adjustment for individual/familial SEP that lowers the risk for ecological fallacies, e.g. regional deprivation being a proxy for other, unmeasured individual or spatial features that are associated with individual SEP and GDD.

Our data and analyses are of exploratory nature and do not allow conclusions on the association of GDD with rurality measured on a neighborhood level or defined as population size rather than population density. Our findings are only valid for the study region including all areas of the German federal state of Brandenburg, which is characterized by a low population density in general and in most municipalities, whereby conclusions for metropolitan areas might differ.

6. Conclusion

Individual deprivation is significantly and strongly linked to developmental delay in preschool children. In this study, we were able to show an additional independent effect of regional deprivation on developmental delay. Rurality measured by population density did not show a significant link to developmental delay in preschool children beyond individual and regional deprivation. We therefore conclude that in addition to family SEP, regional socioeconomic conditions may be risk factors not only for somatic health indicators like weight and obesity (Diez Roux and Mair, 2010; Letarte et al., 2020; Wandschneider et al., 2020), but also for the overall development of children. Both family and regional socioeconomic circumstances are, therefore, of particular interest to public health and social epidemiology to prevent non-communicable diseases and promote individual and population health in children and over the life course.

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Data availability

The data underlying this article cannot be shared publicly due to local and national data protection regulations. All original data are on record and accessible to inspection and will be shared on reasonable request to the corresponding author.

Declaration of competing interest

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2022.102794.

References

Arabiat, D., Jabery, M.A., Kemp, V., Jenkins, M., Whitehead, L.C., Adams, G., 2021. Motor developmental outcomes in children exposed to maternal diabetes during pregnancy: a systematic review and meta-analysis. Int. J. Environ. Res. Publ. Health 18, 1699.

Barnett, S., Roderick, P., Martin, D., Diamond, I., 2001. A multilevel analysis of the effects of rurality and social deprivation on premature limiting long term illness. J. Epidemiol. Community 55, 44–51.

BbgSchulG, 2002. [Law on schools in the federal state of Brandenburg]. https://bravors.brandenburg.de/gesetze/bbgschulg. (Accessed 1 March 2022).

Bellman, M., Byrne, O., Sege, R., 2013. Developmental assessment of children. BMJ 346, e8687.

Ben-Shlomo, Y., Kuh, D., 2002. A life course approach to chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives. Int. J. Epidemiol. 31, 285–293.

Böhm, A., Ellsäßer, G., Lüdecke, K., 2007. The Brandenburg social index: a tool for health and social rporting at regional and communal levels in the analysis of data of school beginngers. Gesundheitswesen 69, 555–559.

Bolker, B., 2015. Exploring Convergence Issues. RPubs. https://rpubs.com/bbolker/lme4_convergence. (Accessed 20 October 2021).

Bowerman, B.L., O'Connell, R.T., 1990. Linear Statistical Models. Thomson Wadsworth.

Brandenburg State Center for Civic Education, 2020. [A book of Brandenburg: a state in keywords]. https://www.politische-bildung-brandenburg.de/publikation/das-brandenbuch-ein-land-stichworten. (Accessed 23 February 2022).

Chen, J.-H., 2014. Asthma and child behavioral skills: does family socioeconomic status matter? Soc. Sci. Med. (1982 115, 38–48.

CSDH, 2008. Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health. Final Report of the Commission on Social Determinants of Health. World health Organization, Geneva. http://www.revistas.usp.br/rdisan/article/view/13190. (Accessed 19 October 2021).

Dahlgren, G., Whitehead, M., 2021. The Dahlgren-Whitehead model of health determinants: 30 years on and still chasing rainbows. Publ. Health 199, 20–24.

Daseking, M., Oldenhage, M., Petermann, F., Waldmann, H.-C., 2009. [The validity of the SOPESS language scale, taking into account the native language]. Gesundheitswesen 71, 663–668.

Diez Roux, A.V., Mair, C., 2010. Neighborhoods and health. Ann. N. Y. Acad. Sci. 1186, 125–145.

Enders, C.K., Tofighi, D., 2007. Centering predictor variables in cross-sectional multilevel models: a new look at an old issue. Psychol. Methods 12, 121–138.

Federal Institute for Building, Urban and Spatial Research, 2022. Indicators and maps for spatial and urban development. https://www.inkar.de/. (Accessed 23 February 2022).

Fox, P.A., Hall, A.P., Schryer, N.L., 1978. The PORT mathematical subroutine library. ACM Trans. Math Software 4, 104–126.

Guner, S.N., Gokturk, B., Kilic, M., Ozkiraz, S., 2011. The prevalences of allergic diseases in rural and urban areas are similar. Allergol. Immunopathol. 39, 140–144.

Hoffmann, D.U., Diefenbach, C., Gräf, C., König, J., Schlecht, J., Schmidt, M.F., Schnick-Vollmer, K., von der Weiden, G., Läßig, A., Daseking, M., Urschitz, M.S., ikidS, P., 2021. [Evaluation of the language tasks of the socio-pediatric development screening for school entrance examinations (SOPESS): results of the prospective child health study ikidS]. Gesundheitswesen 83, 215–221.

Hoffmann, S., Sander, L., Wachtler, B., Blume, M., Schneider, S., Herke, M., Pischke, C.R., Fialho, P.M.M., Schuettig, W., Tallarek, M., Lampert, T., Spallek, J., 2022. Moderating or mediating effects of family characteristics on socioeconomic inequalities in child health in high-income countries - a scoping review. BMC Publ. Health 22, 338.

Joens-Matre, R.R., Welk, G.J., Calabro, M.A., Russell, D.W., Nicklay, E., Hensley, L.D., 2008. Rural-urban differences in physical activity, physical fitness, and overweight prevalence of children. J. Rural Health: Off. J. Am. Rural Health Assoc. Natl. Rural Health Care Assoc. 24, 49–54.

Johnson, A., Mohamadi, A., 2015. Urban-rural differences in childhood and adolescent obesity in the United States: a systematic review and meta-analysis. Child. Obes. 11 https://doi.org/10.1089/chi.2014.0085 ePub.

Jonsson, K.R., Vartanova, I., Södergren, M., 2018. Ethnic variations in mental health among 10-15-year-olds living in England and Wales: the impact of neighbourhood characteristics and parental behaviour. Health Place 51, 189–199.

Khan, I., Leventhal, B.L., 2022 Jan. Developmental Delay. In: 2021 Aug 4. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing. PMID: 32965902.

Khanam, R., Nghiem, S., 2016. Family income and child cognitive and noncognitive development in Australia: does money matter? Demography 53, 597–621.

Kitchen, C., Hatef, E., Chang, H.Y., Weiner, J.P., Kharrazi, H., 2021. Assessing the association between area deprivation index on COVID-19 prevalence: a contrast between rural and urban U.S. jurisdictions. AIMS Public Health 8, 519–530. Center for Population Health IT, Department of Health Policy, Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA, Division of Health Sciences Informatics, Johns Hopkins School of Medicine, Baltimore, MD, USA.

Krieger, N., 2001. Theories for social epidemiology in the 21st century: an ecosocial perspective. Int. J. Epidemiol. 30, 668–677.

Krieger, N., 2008. Ladders, pyramids and champagne: the iconography of health inequities. J. Epidemiol. Community 62, 1098–1104.

Kroll, L.E., Schumann, M., Hoebel, J., Lampert, T., 2017. Regional health differences – developing a socioeconomic deprivation index for Germany. J. Health Monit. 2, 98–114.

Lampert, T., Kroll, L.E., Kuntz, B., Hoebel, J., 2018. Health inequalities in Germany and in international comparison: trends and developments over time. J. Health Monit. 3 (S1) https://doi.org/10.17886/RKI-GBE-2018-036.

Lampert, T., Kuntz, B., 2019. Bundesgesundheitsblatt - Gesundheitsforsch. - Gesundheitsschutz 62, 1263–1274.

Lampert, T., Müters, S., Kuntz, B., Dahm, S., Nowossadeck, E., 2019. Beschreibung der gesundheitlichen Lage in Ost und West sowie deren Entwicklung in den letzten 30 Jahren: [Description of the health situation in East and West and its development in the last 30 years]. https://doi.org/10.25646/6076.

Letarte, L., Pomerleau, S., Tchernof, A., Biertho, L., Waygood, E.O.D., Lebel, A., 2020. Neighbourhood effects on obesity: scoping review of time-varying outcomes and exposures in longitudinal designs. BMJ Open 10, e034690.

Mahase, E., 2019. A decade on from Marmot, why are health inequalities widening? BMJ 365, l4251.

Meijer, M., Röhl, J., Bloomfield, K., Grittner, U., 2012. Do neighborhoods affect individual mortality? A systematic review and meta-analysis of multilevel studies. Soc. Sci. Med. (1982 74, 1204–1212.

Menard, S., 2002. Applied Logistic Regression Analysis, 2nd. SAGE Publications, Thousand Oaks.

Ministry of Labor, Social Affairs, Health, Women and Family of the federal state of Brandenburg, 2020. [Handbook for the child and youth health service in the state of Brandenburg. Guidelines for the uniform implementation and documentation of pediatric and adolescent medical examinations]. https://lavg.brandenburg.de/lavg/de/gesundheit/gesundheitsberichterstattung/methoden-und-handlungshilfen/. (Accessed 20 October 2021).

Moreno-Llamas, A., García-Mayor, J., de La Cruz-Sánchez, E., 2021. Urban-rural differences in trajectories of physical activity in Europe from 2002 to 2017. Health Place 69, 102570.

Nash, J.C., 2014. On best practice optimization methods in R. J. Stat. Software 60 (2), 1–14.

Nguyen, T.H., Götz, S., Kreffter, K., Lisak-Wahl, S., Dragano, N., Weyers, S., 2021. Neighbourhood deprivation and obesity among 5656 pre-school children—findings from mandatory school enrollment examinations. Eur. J. Pediatr. 180, 1947–1954.

Office for Health Improvement and Disparities, 2022. Public Health Profiles 2022. Crown copyright. https://fingertips.phe.org.uk/profile-group/marmot/profile/marmot-indicators. (Accessed 16 September 2021).

Pediatric and Adolescent Medical Service Saxony-Anhalt, 2018. [Handout for the school entrance examination in Saxony-Anhalt (excerpt)]. https://verbraucherschutz.sachsen-anhalt.de/fileadmin/Bibliothek/Politik_und_Verwaltung/MS/LAV_Verbraucherschutz/service/gbe/berichte/2018_12_Handreichung_SEU_Auszug_ohne_SEBES.pdf. (Accessed 20 October 2021).

Petermann, F., 2009. [SOPESS - Social Pediatric Development Screening for School Entry Examinations]: [Theoretical and Statistical Foundations for Test Construction, Standardization and Validation]. State Institute for Health and Work of the State of North Rhine-Westphalia, Düsseldorf.

Petermann, F., Macha, T., 2005. [Psychological Tests for Pediatricians]. Hogrefe, Göttingen, Bern, Wien.

Piel, F.B., Fecht, D., Hodgson, S., Blangiardo, M., Toledano, M., Hansell, A.L., Elliott, P., 2020. Small-area methods for investigation of environment and health. Int. J. Epidemiol. 49, 686–699.

Rubin, M.S., Clouston, S.A.P., Edelstein, B.L., 2021. Small-area socioeconomic status and children's oral health in a safety-net care delivery setting. J. Publ. Health Dent. 81, 3–11.

Sansavini, A., Favilla, M.E., Guasti, M.T., Marini, A., Millepiedi, S., Di Martino, M.V., Vecchi, S., Battajon, N., Bertolo, L., Capirci, O., Carretti, B., Colatei, M.P., Frioni, C., Marotta, L., Massa, S., Michelazzo, L., Pecini, C., Piazzalunga, S., Pieretti, M., Rinaldi, P., Salvadorini, R., Termine, C., Zuccarini, M., D'Amico, S., de Cagno, A.G., Levorato, M.C., Rossetto, T., Lorusso, M.L., 2021. Developmental language disorder: early predictors, age for the diagnosis, and diagnostic tools. A scoping review. Brain Sci. 11, 654.

Schmitz-Veltin, A., 2006. [Living conditions in demographic change]. Raumforsch. Raumordn. 64, 343–354.

Schneider, S., Holzwarth, B., 2021. [Health differences between town and country - proposal for an interdisciplinary explanatory mode]. In: Weidmann, C., Reime, B. (Eds.), Health Promotion and Care in Rural Areas]. Hogrefe, pp. 19–33.

Stafford, M., Marmot, M., 2003. Neighbourhood deprivation and health: does it affect us all equally? Int. J. Epidemiol. 32, 357–366.

Statistical Office of the European Union, 2021. Applying the degree of urbanisation: a methodological manual to define cities, towns and rural areas for international comparisons : 2021 edition. https://op.europa.eu/en/publication-detail/-/publication/484c6825-8540-11eb-af5d-01aa75ed71a1/. (Accessed 16 September 2021).

Statistics Berlin Brandenburg, 2019. [Statistical report: area survey according to the type of actual use in the state of Brandenburg 2018]. (Accessed 20 October 2021).

Statistics Berlin Brandenburg, 2022. Spatial references. https://www.statistik-berlin-Brandenburg.de/raumbezuege. (Accessed 23 February 2022).

Stich, H., Schlinkmann, K.M., Mikolajczyk, R., 2018. [Competing validity of developmental diagnostics at the time of the school entrance examination - results of a full survey in an Upper Bavarian district]. Gesundheitswesen 80, S22-S28.

Strömberg, U., Baigi, A., Holmén, A., Parkes, B.L., Bonander, C., Piel, F.B., 2021. A comparison of small-area deprivation indicators for public-health surveillance in Sweden. Scand. J. Publ. Health. https://doi.org/10.1177/14034948211030353. Epub ahead of print.

Teymoori, A., Côté, S.M., Jones, B.L., Nagin, D.S., Boivin, M., Vitaro, F., Orri, M., Tremblay, R.E., 2018. Risk factors associated with boys' and girls' developmental trajectories of physical aggression from early childhood through early adolescence. JAMA Netw. Open 1, e186364.

Valet, R.S., Perry, T.T., Hartert, T.V., 2009. Rural health disparities in asthma care and outcomes. J. Allergy Clin. Immunol. 123, 1220–1225.

Visser, K., Bolt, G., Finkenauer, C., Jonker, M., Weinberg, D., Stevens, Gonneke W.J. M., 2021. Neighbourhood deprivation effects on young people's mental health and well-being: a systematic review of the literature. Soc. Sci. Med. (1982 270, 113542.

Voigtländer, S., Mielck, A., Razum, O., 2012. [The Importance of small scale context for health: designing an explanatory model. Gesundheitswesen 74, 702–709.

Wagenmakers, E.-J., Farrell, S., 2004. AIC model selection using Akaike weights. Psychonomic Bull. Rev. 11, 192–196.

Waldmann, H.-C., Oldenhage, M., Petermann, F., Daseking, M., 2009. [Screening of the development status at the school enrollment examination: validity of the cognitive scales of the SOPESS]. Gesundheitswesen 71, 656–662.

Wandschneider, L., Sauzet, O., Breckenkamp, J., Spallek, J., Razum, O., 2020. Small-area factors and their impact on low birth weight—results of a birth cohort study in bielefeld, Germany. Front. Public Health 8, 136.

WHO, 2020. Improving early childhood development: WHO ECD guideline. https://www.who.int/publications-detail-redirect/97892400020986. (Accessed 15 September 2021).

Zablotsky, B., Black, L.I., 2020. Prevalence of children aged 3–17 years with developmental disabilities, by urbanicity: United States. In: 2015–2018. National Health Statistics Reports; no 139. Hyattsville. MD: National Center for Health Statistics.