Intersectional analysis of social disparities in type 2 diabetes risk among adults in Germany: results from a nationwide population-based survey

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Research Article

Keywords: Diabetes mellitus, diabetes risk, prevention, intersectionality, social determinants, population-based survey

Posted Date: October 24th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3438527/v1

Additional Declarations: No competing interests reported.

Abstract

Background

Differences in type 2 diabetes risk have been reported for several sociodemographic determinants including sex/gender or socioeconomic status. From an intersectional perspective, it is important to not only consider the role of social dimensions individually, but also their intersections. This allows for a deeper understanding of diabetes risk and preventive needs among diverse population groups.

Methods

As an intersectionality-informed approach, multilevel analysis of individual heterogeneity and discriminatory accuracy (MAIHDA) was used in a population-based sample of adults without known diabetes in Germany from the cross-sectional survey “Disease knowledge and information needs – Diabetes mellitus (2017)”. Diabetes risk was assessed by the German Diabetes Risk Score (GDRS, range 0-122 points) estimating the individual risk of developing type 2 diabetes within the next 5 years based on established self-reported risk factors. Nesting individuals in 12 intersectional strata defined by combining sex/gender, educational level, and history of migration, we calculated measures to quantify the extent to which individual differences in diabetes risk are explained at strata level, and how much this is due to additive or multiplicative intersectional effects of social determinants.

Results

Drawing on data of 2,253 participants we found good discriminatory accuracy of intersectional strata (variance partition coefficient = 14.00% in the simple intersectional model). Model-predicted GDRS means varied between 29.97 (corresponding to a “low risk” of < 2%) in women with high educational level and a history of migration, and 52.73 (“still low risk” of 2–5%) in men with low educational level without a history of migration. Variance in GDRS between strata was mainly explained by additive effects of social determinants (proportional change in variance to intersectional interaction model = 77.95%) with being male and having low educational level being associated with higher GDRS. There was no evidence of multiplicative effects in individual strata.

Conclusions

Type 2 diabetes risk differed between intersectional strata and can to some extent be explained at strata level. The role of intersectional effects was minor and needs to be further investigated. Findings suggest a need for specific preventive measures targeted at large groups with increased diabetes risk, such as men and persons with low educational level.

Background

Diabetes mellitus is a noncommunicable disease with high relevance for public health in many countries around the world. Globally, more than half a billion people were estimated to have diabetes mellitus, with type 2 diabetes accounting for more than 90% of cases. [1]. For Germany, the 12-months prevalence of self-reported diabetes in adults was estimated at 8.9% in 2019/2020 [2]. Diabetes represents the fifth most important cause of burden of disease in terms of disability-adjusted life years among men in Germany and the sixth most important cause among women, largely due to type 2 diabetes [3] causing about 7.4 billion euros of direct medical costs per year [4].

At the same time, preventive potential regarding type 2 diabetes is relatively high. The global increase in age-standardized incidence and prevalence over the last decades is considered to be mainly due to changes in behavioural and environmental risk factors [5]. These include aspects like poor dietary patterns, low levels of physical activity and increased sedentary time, all associated with obesity as a main risk factor of type 2 diabetes besides age [6, 7]. These behavioural aspects are potentially modifiable and can therefore be targeted by preventive measures.

Importantly from a public health perspective, there is consistent evidence for social inequalities in the occurrence of diabetes and its risk factors, which can guide prevention approaches. There are sex/gender differences in diabetes prevalence, with more men being affected than women, both globally (9.0% vs. 7.9%, [8]) as well as in Germany (9.6% vs. 8.2%, [2]). Differences in risk factors between men and women are more diverse though [9]. For example, men were less likely to lead a health-promoting lifestyle than women considering aspects like smoking or fruit and vegetable intake, but showed higher levels of physical activity based on results of survey data from Germany [10]. For obesity, the prevalence is higher in women globally [11], though differences in obesity between men and women in Germany have decreased or even disappeared [12, 13].

Socioeconomic status represents another relevant social determinant in diabetes. A low socioeconomic status, typically indicated by low educational level, low income, or less qualified occupation, has consistently been associated with higher risk of developing diabetes [14, 15]. For Germany [16], educational level was found to be a more pronounced predictor for diabetes compared to income and occupation [17, 18]. Furthermore, there is considerable evidence for socioeconomic inequality across diverse risk factors for diabetes like obesity, smoking, or physical inactivity, which are more prevalent among people with low socioeconomic status [10, 13].

Furthermore, differences in diabetes depending on migration status have been observed in Europe. For persons with a history of migration, a higher diabetes prevalence as well as a higher diabetes mortality compared to those without a history of migration have been reported [19, 20]. Degrees of increased risk seem to depend on the region from which people have migrated though, with populations with migration histories from South Asia as well as Middle Eastern and North African countries being especially at risk [19, 20]. In this light, results from other countries should only be generalized to Germany with caution, as countries can differ in terms of their specific migration patterns. In Germany, health data on people with a history of migration has long been insufficient though [21]. Analyses in this field face challenges as public health data often contain little information on history of migration [22, 23] and differ in their definition of migration-related variables [23]. This lack of information holds especially true for secondary data collected for different purposes. Consequently, there is a need to investigate the relevance of migration history for the risk of developing diabetes among the German population.

Given the findings on the role of individual social determinants, public health researchers have argued that health inequalities need to be examined beyond single axes of social dimensions, proposing an intersectional perspective that takes into account the complex interplay of such determinants in the life of individuals, and the differential effects of social positions at the unique intersections of those dimensions [24]. Intersectionality, as conceptualized by Black feminist scholars (e.g., Crenshaw [25]) is thus considered a valuable framework for public health research [26] and has been increasingly adopted in quantitative health research after having been primarily applied in qualitative studies [27]. Intersectional theory assumes that dimensions of social position such as sex/gender or socioeconomic status intersect at the individual level and jointly shape a person's experience in ways that reflect systems of privilege and oppression at the structural level [26, 27]. Moreover, the advantages and disadvantages that result from being in a social position, for example in relation to health, do not correspond to a simple additive accumulation of the effects of intersecting dimensions, but can be characterized by differential multiplicative intersectional effects [24, 28].

In epidemiological research on diabetes, Wemrell et al. [29] applied an intersectional perspective in their quantitative analysis of Swedish registry data of persons aged 40 and older. They did not only examine to what extent social determinants such as age, gender, income, education, and migration status predict type 2 diabetes prevalence, but also how much intersectional strata defined by the combination of these determinants can additionally contribute to differences in the prevalence. They found a very heterogeneous distribution of diabetes prevalence with respect to the included social dimensions: For instance, elderly migrated men with low income and low education levels had a very high risk of type 2 diabetes, while women who did not migrate, aged 40-49 years old, with high income and high education levels had a very low risk. Further, the discriminatory accuracy of the combined information from the included dimensions was acceptable.

Among other methods, multilevel analysis of individual heterogeneity and discriminatory accuracy (MAIHDA) has been increasingly proposed as an appropriate intersectionality-informed approach for the quantitative study of health inequalities [24, 30]. Essentially, in a MAIHDA analysis, individuals are located within strata based on their combination of social dimension characteristics and in a next step, health outcomes of interest are modelled using multilevel regression, i.e. mixed models, with individuals considered to be nested in those intersectional strata [31]. Following Evans et al. [32], the aims of the MAIHDA approach are threefold: 1. to map differences in health outcomes across intersectional strata by estimating means or frequencies for all strata, 2. to quantify the variance within and between strata by calculating measures indicating discriminatory accuracy of intersectional strata, and 3. to estimate multiplicative intersectional effects for all strata.

A study by Holman et al. [33] applying MAIHDA to map intersectional inequalities in biomarkers using English national data included HbA1c, a measure of blood glucose concentration over the past 2 to 3 months used to diagnose diabetes. Examining intersectional strata defined by gender, ethnicity, education, and income, they found some between-strata variance for HbA1c with lowest levels in White women with high education and high income, and highest levels in Black and Minority Ethnicity men with low education and low income. This variation seemed to be fully explained by additive main effects of social dimensions included.

Building on this first evidence on the role of intersectionality in the context of diabetes, we aimed to address the potential for quantitative examination of social inequalities in diabetes risk in Germany by adopting an intersectional perspective. To potentially inform public health decisions, we shed light on the question whether there are constellations of social position that are at a particularly high risk to develop diabetes and could therefore benefit especially from targeted measures. Filling the existing gap on an intersectional approach to diabetes prevention, we performed a MAIHDA analysis using data on diabetes risk based on health behaviour and other risk factors from a sample of persons without known diabetes from a nationwide population-based survey in Germany to answer the following questions:

1. To what extent does diabetes risk differ between individuals from different intersectional strata defined by sex/gender, educational level, and history of migration?

2. To what extent do differences in diabetes risk among different intersectional strata result from additive main effects and from multiplicative intersectional effects of the social dimensions defining these strata?

Methods

Study design and sample

In this study, we used data from the nationwide telephone interview survey “Disease knowledge and information needs – Diabetes mellitus (2017)” conducted by the Robert Koch Institute (RKI) in cooperation with the Office for National Education and Communication on Diabetes Mellitus of the German Federal Centre for Health Education (BZgA) and the Institute of Medical Sociology and Rehabilitation Science of the Charité – Universitätsmedizin Berlin. The survey and its sampling procedure [34, 35] as well as psychometric properties of multi-item scales applied in the study [36] have previously been described in more detail elsewhere.

The target population were adults (≥ 18 years) with sufficient German language skills to participate in the standardized interview. Computer-assisted telephone interviews were carried out by trained personnel from a market and social research institute from September to December 2017 using a dual frame approach. A sample of landline and cell phone numbers was randomly generated with the aim of providing a representative sample of all private households reachable by phone at a national level.

Sampling proceeded in two steps beginning with the drawing of a sample from the general adult population applying the Kish selection grid to randomly select members from multi-person households. Depending on their response to the question “Have you ever been diagnosed with diabetes by a doctor?” (“yes” or “no”), participants were interviewed based on a questionnaire for individuals with or without a diagnosis of diabetes. This phase resulted in the inclusion of 263 persons with and 2,327 persons without self-reported diabetes. The response rate was 17.9%, calculated according to the standard of the American Association for Public Opinion Research as proportion of realized interviews in relation to all households potentially reachable by phone in Germany, i.e., response rate 3 [35]. In a second sampling phase with direct screening for persons with diagnosed diabetes, 1,216 adults with diabetes were included, resulting in a study sample of 3,806 people in total (2,327 individuals without diabetes and 1,479 individuals with diabetes).

Because of the preventive perspective of this study, only individuals without diabetes were considered. From the total number of 2,327 participants without known diabetes, 7 persons (0.3%) with missing data for educational level or history of migration were excluded from the analysis. Furthermore, values for diabetes risk could not be calculated for 67 persons (2.9%), because of missing data regarding components of the diabetes risk score. Thus, models were estimated based on data of 2,253 persons.

Prior to the interview, all participants were informed about study aims and procedure, the voluntary nature of their participation, as well as data protection regulations, and gave verbal informed consent to participate. The “Disease knowledge and information needs – Diabetes mellitus (2017)” survey was approved by the ethics committee of the Berlin Chamber of Physicians in August 2017 (Ärztekammer Berlin; No. Eth-23/17) and the Federal Commissioner for Data Protection and Freedom of Information.

Variables

Outcome

The outcome of interest in this study was diabetes risk assessed by the German Diabetes Risk Score (GDRS) [37, 38]. Developed by the German Institute of Human Nutrition Potsdam-Rehbrücke (DIfE), the GDRS enables to predict the individual risk for developing type 2 diabetes within the next 5 years based on non-invasively assessed factors. The GDRS is an established and validated tool that has been shown to accurately predict 5-year-risk of type 2 diabetes [37, 39, 40]. In this study, an updated and simplified version of the GDRS [41] was used that has also been validated [40]. The score is calculated by assigning points to the following risk factors as categorical score components: age, waist circumference, body height, prevalent hypertension, smoking, physical activity, coffee consumption, whole grain intake, meat intake and family history of diabetes. Details on the calculation can be found elsewhere [41]. GDRS values can range from 0 to 122. According to recommendations by the DIfE on the communication of individual risks based on GDRS results a score < 46 points can be interpreted as low risk (corresponding to a risk < 2%), 46–56 points as still low risk (≈ 2–5%), 57–63 points (≈ 6–10%) as elevated risk and a score > 63 points as high to very high risk (> 10%) of developing type 2 diabetes within the next 5 years [38].

In the “Disease knowledge and information needs – Diabetes mellitus (2017)” survey prevalent hypertension was assessed by self-report on physician-diagnosed hypertension. Smoking was measured by asking whether participants currently or formerly smoked and for the average number of cigarettes, cigarillos or cigars smoked daily (< 20 or ≥ 20). Physical activity was assessed by the information whether a person was physically active for at least 5 hours per week or not. Coffee consumption was measured in cups of coffee drunk per day. Whole grain intake was assessed by the average sum of whole grain slices and muesli portions consumed daily. Red meat intake was obtained by asking how frequently a person consumed beef, pork, or lamb. Family history of diabetes was assessed by self-report on diagnoses of diabetes in biological parents and siblings. Since waist circumference was not assessed in the interview it was estimated based on information on height, weight and age using separate equations for men and women (see Heidemann et al. [42] for more detail). Equations were obtained from data of the German Health Interview and Examination Survey for Adults (2008–2011) that provided comprehensive information on measured and self-reported anthropometric variables [43].

Intersectional variables

The social dimensions examined in this study were sex/gender, educational level, and history of migration. In the survey sex/gender was assessed by categories “male” and “female” as response options to the question "Are you male/female?". Educational level was measured by the Comparative Analysis of Social Mobility in Industrial Nations classification (CASMIN) using a categorization into “low”, “middle” and “high educational level”: incomplete general education, general elementary education or basic vocational qualification being classified as “low”; intermediate general education or vocational qualification or full maturity certificates being classified as “middle”; and lower or higher tertiary education being classified as “high educational level” [44]. History of migration was defined as having at least one parent who was not born in Germany. Otherwise, participants were classified as “not having history of migration”.

By combining all possible categories of sex/gender, educational level, and history of migration 12 intersectional strata were obtained (2x3x2). The classifications described above were selected with the aim to investigate relevant strata building on the state of research on social determinants of diabetes risk, while accounting for sufficiently large case numbers.

Since the risk of developing diabetes increases with age [1], age is a component of the GDRS used to assess diabetes risk as outcome of interest. We therefore did not include age as social dimension to construct intersectional strata. To examine whether age was driving effects observed in relation to included social dimensions, we ran a sensitivity analysis including age in years as a continuous control variable.

Statistical analyses

As previously described [34], a survey-specific weighting factor was used in all analyses to increase representativeness of results. It was computed to compensate for deviations in the distribution of age, sex/gender, educational level, and federal state of residence in the study sample compared to the resident population in Germany as of December 31, 2016, reported by the Federal Statistical Office. Descriptive statistics were calculated using the R packages “survey” (version 4.1.1; [45]) and “srvyr” (version 1.2.0; [46]), creating a survey design object with the weighting factor.

We performed a MAIHDA [28, 30] running two consecutive multilevel linear regressions to model diabetes risk with individuals at level one nested in 12 intersectional strata at level two. Firstly, as **null model** or **simple intersectional model**, we fitted an **unadjusted random intercepts model** including the intersectional strata as random effects in addition to an intercept.

The first model can be denoted as follows: $y_{ij} = \beta_0 + u_j + e_{ij}$

with y_{ij} indicating the diabetes risk score of an individual i ($i = 1, \ldots, n_j$) in stratum j ($j = 1, \ldots, J$), β_0 denoting the intercept, u_j indicating stratum-level random effects assumed to be normally distributed with mean 0 and variance σ_u^2, and e_{ij} denoting individual-level residuals assumed to be normally distributed with mean 0 and variance σ_e^2. Based on this variance component model, total variance in diabetes risk scores is partitioned in variance within intersectional strata σ_e^2 and variance between intersectional strata σ_u^2, the latter being attributable to both additive main effects and possible multiplicative intersectional effects of examined social dimensions in this unadjusted model.

In a next step, we fitted a **second model, the intersectional interaction model, adjusted for the main effects** of the social dimensions constructing the intersectional strata of interest, by including variables for sex/gender, educational level, and history of migration as fixed effects in addition to an intercept and stratum-level random effects as in the null model.

Hence, the second model can be denoted as follows: $y_{ij} = \beta_0 + \beta_1 x_{1j} + \beta_2 x_{2j} + \beta_3 x_{3j} + \beta_4 x_{4j} + u_j + e_{ij}$

with indicator variables x_{1j} for male, x_{2j} for having a history of migration, as well as x_{3j} for middle and x_{4j} for low educational level, and corresponding regression coefficients $\beta_1, \ldots, \beta_4$. Assumptions on the distribution of stratum-level random effects and individual-level residuals corresponded to those in model 1. The estimation of stratum-level random effects is not affected by which category of a social dimension is chosen as a reference [28, 32]. Adjusting for main effects of social dimensions allows to isolate the proportion of between-strata variance in diabetes risk scores potentially attributable to stratum specific two-way or higher interactions of those variables, i.e., multiplicative intersectional effects, from the proportion explained by additive main effects.

Consequently, several measures of interest could be determined based on these two models:

1. We calculated variance partition coefficients (VPC) reflecting the proportion of total variance in diabetes risk scores explained by variance between intersectional strata:

$$VPC = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_e^2}$$

VPCs have been considered as measure of discriminatory accuracy of intersectional strata [30] and correspond to the intraclass correlation (ICC) in both models applied. The higher the VPC based on model 1, the higher the relevance of intersectional strata in explaining individual differences in diabetes risk scores [47]. The higher the VPC based on model 2, the higher the relevance of multiplicative intersectional effects of social dimensions defining the strata in explaining these differences [47].

2. Based on model 1, predicted means for diabetes risk scores and 95% confidence intervals for all intersectional strata were obtained.
3. To quantify the extent to which between-strata variance can be explained by added fixed effects for main effects the proportional change in variance (PCV) was calculated as follows:

$$PCV = \frac{\sigma^2_{u(1)} - \sigma^2_{u(2)}}{\sigma^2_{u(1)}}$$

It reflects proportional change in variance between strata from the simple intersectional model to the intersectional interaction model. The higher the PCV, the stronger variance in diabetes risk scores between strata is attributable to additive main effects of social dimensions included. Accordingly, 1 - PCV provides information on the relevance of multiplicative intersectional effects in the sense of stratum specific two-way or higher interactions.

4. Further, to examine potential multiplicative intersectional effects within each intersectional stratum, stratum-level residuals and 95% confidence intervals were determined by subtracting the predicted mean based on main effects from the total predicted mean for each stratum based on model 2. Thus, stratum-level residuals reflect the extent to which predicted strata mean values deviate from expected additive main effects of the combination of social dimensions.

We estimated all models using a restricted maximum likelihood (REML) procedure with the R package “lme4” (version 1.1.32; [48]) using “bootpredictlme4” package (version 0.1; [49]) to bootstrap standard errors of predicted means. The weighting factor was rescaled using the “datawizard” package (version 0.7.1; [50]) to estimate the models.

Data management was conducted with IBM SPSS Statistics (version 27) and analyses were performed using R statistical software (version 4.2.2, [51]).

Results

The 2,253 individuals had a mean age of 51.7 years (SD = 18.6), 50.8% were female and 80.7% had no history of migration (Table 1). Among the participants, 26.2% had a high level, 40.6% had a middle level and 33.1% had a low level of education according to the CASMIN classification.

Table 1. Sample characteristics (n=2253)

Variables	*n*	Mean (*SD*) or %
Age (years), mean (*SD*)		51.7 (18.6)
Sex/Gender (%)		
Female	1262	50.8
Male	991	49.2
History of migration (%)		
No history of migration	1912	80.7
History of migration	341	19.3
Educational level (CASMIN) (%)		
High	974	26.2
Middle	956	40.6
Low	323	33.1

Sample sizes (n) are unweighted. Mean (SD) and percentages are weighted.

The number of observations per intersectional stratum was higher than 20 in all 12 strata, with the smallest number of observations being 23 for men with low educational level and a history of migration (Table 3).

Table 2 provides results from MAIHDA models 1 and 2. The VPC of the simple intersectional model (unadjusted null model) was 14.00%, indicating the amount of individual variance in diabetes risk scores that was at the intersectional strata level. After including fixed effects for sex/gender, history of migration and educational level in the intersectional interaction model, the VPC dropped to 3.09%. The PCV in model 2 was 77.95%, suggesting that differences in diabetes risk scores between intersectional strata resulted mostly from additive effects of the social dimensions analysed. Accordingly, 22.05% of between-strata variance in diabetes risk score remained unexplained by additive main effects. Based on fixed effects estimates, diabetes risk was higher for men than for women, lower for people with a history of migration than for people without, as well as higher for persons with low educational level compared to high educational level.

Table 2. Parameter estimates from MAIHDA intersectional models for diabetes risk score (n=2253)

	Model 1. Simple intersectional model		Model 2. Intersectional interaction model	
	Estimate	**(95% CI)**	**Estimate**	**(95% CI)**
Fixed effects				
Intercept	38.98	(35.04, 42.91)	36.00	(31.69, 40.24)
Sex/Gender				
Female (reference)			-	-
Male			4.18	(0.06, 8.32)
History of migration				
No history of migration (reference)			-	-
History of migration			-5.83	(-10.12, -1.67)
Educational level (CASMIN)				
High (reference)			-	-
Middle			1.03	(-3.79, 5.93)
Low			10.89	(5.74, 16.15)
Measures of variance				
Between-strata variance	43.79	(13.79, 94.59)	8.57	(0.25, 28.60)
Within-strata variance	269.00	(247.37, 289.86)	269.09	(247.52, 289.98)
VPC (%)	14.00		3.09	
PCV (%)			77.95	
1-PCV (%)			22.05	

95% CI = 95% confidence intervals; PCV = proportional change in the between-strata variance; VPC = variance partition coefficient.

As depicted in Figure 1 and Table 3, predicted means of diabetes risk score based on model 1 varied between intersectional strata ranging from 29.97 (95%-CI: 16.81, 43.12) in women with high educational level and a history of migration indicating low actual risk to 52.73 (95%-CI: 38.90, 66.57) in men with low educational level and no history of migration indicating still low actual risk according to classification for risk communication based on GDRS by the DIfE [38].

Table 3. Predicted GDRS points with 95% CIs based on model 1 by intersectional strata

History of migration		Sex/Gender		Educational level					
Yes	No	Male	Female	Low	Mid	High	*n*	Predicted GDRS points	(95% CI)
x		x		x			23	39.08	(26.55, 51.61)
x			x	x			33	40.31	(27.39, 53.23)
x		x			x		59	32.77	(19.54, 45.99)
x			x		x		80	35.80	(22.75, 48.86)
x		x				x	75	37.98	(24.49, 51.46)
x			x			x	71	29.97	(16.81, 43.12)
	x	x		x			110	52.73	(38.90, 66.57)
	x		x	x			157	47.69	(34.79, 60.58)
	x	x			x		323	40.17	(27.08, 53.25)
	x		x		x		494	36.96	(24.11, 49.81)
	x	x				x	401	41.49	(28.41, 54.57)
	x		x			x	427	32.78	(19.78, 45.78)

95% CI = 95% confidence intervals.

Stratum-level residuals, i.e., differences between predicted means based on total effects and predicted means based on fixed main effects only for each stratum, are depicted in Figure 2. 95%-CI include 0 for all strata and thus show no evidence for multiplicative intersectional effects.

As a sensitivity analysis, we reran model 1 and 2 with an additional control for age. This yielded a slightly lower VPC (model 1: 12.75%; model 2: 0.82%) and a higher PCV (93.55%), thus still following the overall tendencies from the main analysis (see Additional file 1: Table S1). The fixed effect estimates differed from the main analysis in that the main effect of a history of migration was not significantly different from 0, but the effect for middle education level was, with individuals with mid-level education having higher diabetes risk scores compared to individuals with high educational level. This result indicates that the main effect of history of migration might be confounded by age.

Discussion

In the present study, we investigated diabetes risk in persons without known diabetes in Germany with an intersectionality-informed approach. To this end, we used data from a nationwide population-based sample to perform MAIHDA on diabetes risk scores of individuals nested in intersectional strata defined by the combination of social dimensions sex/gender, educational level, and history of migration. Multilevel linear regressions allowed us to examine the extent to which individual differences in diabetes risk scores are explained at strata level, and how much these differences are due to additive main effects or multiplicative intersectional effects of the social determinants.

Model-predicted diabetes risk scores showed disparities among the 12 strata, with variations of approximately 20 points between the stratum with the lowest risk and the one with the highest: The stratum with the lowest risk to develop type 2 diabetes within the next five years consisted of women with high educational level and a history of migration. On the other hand, the stratum comprising men with low educational level without a history of migration displayed the highest risk. The calculated variance components measure suggested that 14.00% of the individual variance in diabetes risk score could be attributed to between-strata variance. According to Axelsson Fisk et al. [47], this VPC can be considered as indicating a good level of discriminatory accuracy of intersectional strata, and is rather high compared to other studies applying MAIHDA to health outcomes [52]. Thus, a relevant proportion of the variance in diabetes risk scores can be explained at strata level, highlighting the role of social determinants in the risk of developing type 2 diabetes.

With a PCV of 77.95%, most of the variance explained by intersectional strata could be attributed to additive main effects of sex/gender, educational level, and history of migration. The directions of the main effects are in line with the existing evidence on sex/gender [9] and educational level [14] as determinants of diabetes risk: being male and having a low educational level was associated with higher risk of developing diabetes compared to being female and having a high educational level, respectively. When controlling for age as part of a sensitivity analysis, mid-level education was also associated with higher diabetes risk scores compared to high educational level, supporting the robust effect of educational level. In contrast, the direction of the main effect of history of migration, which suggests a higher risk for individuals without a history of migration, is at odds with studies from Europe [19] that described a higher risk among individuals with migration history. The result of the present analysis, however, may be due to a confounding of the variable migration history with age in the present sample: People with a history of migration are on average younger than persons without history of migration in the sample, as well as in German society [53]. As a likely consequence, the fixed effect coefficient for migration history was not significantly different from 0 when controlling for age, unlike the fixed effect coefficients for male sex/gender and low educational level. Further, disparities in diabetes risk related to migration have been attributed to differences in socioeconomic status, lifestyle and health behaviours, biological aspects such as the pathogenesis of insulin resistance, and healthcare access and thus appear to vary with the region from which people migrated [15, 54] [55]. However, due to the small number of cases, it was not possible to distinguish between different regions of origin of the individuals with migration history, which could have otherwise clarified the uncertain effect of migration history. Therefore, results on history of migration in this analysis should thus be interpreted with caution.

Given that 22.05% of between-strata variance in diabetes risk scores remain unexplained by main effects (see 1-PCV), the differences in diabetes risk scores between strata might be attributable, albeit to a relatively lesser extent, to more complex interactions of the defining social dimensions in terms of multiplicative intersectional effects. However, estimating stratum-level residuals for the 12 individual strata revealed no significant deviation of the predicted stratum means from the expected values based on additive main effects of a combination of social dimensions. This could be in part due to the fact that numbers of observations in individual strata were too small to detect multiplicative effects at specific intersections of social dimensions. The partially small group size also did not allow for further differentiation between plausible subgroups, for instance according to regions to which the history of migration of individuals refers, or according to more differentiated gradations of educational level. These might have explained the differences in model-predicted diabetes risk scores more precisely but had to be collapsed for this study.

Overall, the results are consistent with the findings on diabetes prevalence in Swedish registry data [29] and the MAIHDA on HbA1c in English national data [33]. These studies found large disparities between intersectional strata, with strata containing men with low education having less favourable outcomes and women with high education having more favourable outcomes in comparison. However, in line with the body of research already outlined, having migrated or belonging to an ethnic minority was associated with less favourable outcome values in each of the two studies. In both cases, the effect of the social position on diabetes prevalence and blood glucose levels was also mainly or even completely attributable to additive main effects of those dimensions, while intersectional effects played a subordinate or no role. In agreement with these findings, our results suggest that multiplicative intersectional effects play a smaller role in the risk of developing diabetes compared to additive effects of individual social determinants. This illustrates how taking an intersectional perspective, through the application of an intersectionality-informed approach such as MAIHDA, allows for a nuanced understanding of how social dimensions shape health outcomes. Investigating the interplay of social dimensions through additive and intersectional effects thus enables a holistic approach to addressing health inequalities and developing tailored public health interventions.

In terms of practical implications, the results of the present study emphasize the need to consider the relevant impact of social position on the risk of developing type 2 diabetes also when planning and implementing prevention measures. In view of limited resources for prevention and health promotion, this raises the question of how precisely interventions to prevent diabetes should be tailored to particular groups. To address social disparities in health, Marmot et al. [56] recommend universal strategies with attention and intensity adjusted to need. According to our findings, it is mainly additive effects of social determinants that explain these social disparities in diabetes risk. This suggests targeting especially men and people with low educational level as large groups at increased risk, rather than addressing specific intersections of social dimensions. The need for tailored prevention strategies is underscored by evidence that these two groups are underserved by existing diabetes prevention measures. For instance, they are less likely to take up preventive services such as health check-ups [57, 58] or programs aimed at promoting healthy lifestyles and behaviour change [59, 60, 61]. In view of these findings, previous studies have successfully pioneered gender-sensitized interventions, such as lifestyle programs aimed at increasing physical activity in overweight men through their followership of their favourite soccer or hockey clubs, yielding positive effects in terms of weight loss [62]. In this sense, mediating variables and processes linked to differences in diabetes risk and prevention in relation to sex/gender as well as level of education should be further investigated to inform the development of tailored interventions accordingly.

Strengths and limitations

To our knowledge, this is the first study examining preventive potential concerning type 2 diabetes within an intersectional framework in persons without known diabetes in Germany. We applied the MAIHDA approach as it is considered a valuable tool to quantitatively investigate intersectional aspects of health inequalities, providing several advantages compared to single-level models [32]. This still novel approach aims to descriptively explore health inequality across observed combinations of the considered social dimensions by mapping predicted outcomes simultaneously for all strata representing these combinations. One strength of MAIHDA is that the approach is aligned with the perspective of intersectional theory. Rather than reproducing notions of privilege and marginalization by examining possible intersectional effects as deviations from a reference group, MAIHDA enables to simultaneously analyse possible intersectional effects in all intersectional strata by examining them as deviations of predicted strata values from expected values based on additive main effects [28]. In this way, also the effects of social positions combining social dimension characteristics of privilege and disadvantage can easily be mapped. Finally, MAIHDA models permit more social dimensions or corresponding categories and multiple resulting combinations to be included in the analysis while still being parsimonious and comparatively easy to interpret, whereas single-level models require the inclusion of a geometrically growing number of interaction terms [28].

Despite these strengths, we must address some limitations. The study sample was obtained using well-established sampling procedures for public health telephone surveys to collect a population-based sample allowing to draw generalizable conclusions on health behaviour and risk factors for diabetes to the German-speaking population [36]. As the response rate was rather low, we included a survey-specific weighting factor in all analyses to compensate for deviations in the study sample compared to the resident population in Germany. It is nevertheless possible that the representativeness of the sample is limited regarding certain characteristics, since, for example, the proportion of people with a history of migration is lower than in the general German population which may be due to recruitment criteria like German language skills. What may further limit the interpretation of results on migration history is the average age difference between participants with and without history of migration. While in line with the situation in the German population, the sensitivity analysis with control for age no longer showed a clear fixed effect of migration history for diabetes risk which suggests a confounding with age. However, calculating the diabetes risk score without taking age into account as a score component cannot be meaningfully performed as there is no corresponding validation. This challenge arises from the fact that the risk of developing type 2 diabetes was calculated by a validated score based on diabetes-related risk factors, including age, to estimate the risk in individuals not yet affected and therefore still eligible for prevention, rather than being assessed by a physician or biomarkers. Although the GDRS has shown excellent discriminatory accuracy for predicting a type 2 diabetes diagnosis within 5 years, the assignment of points might be flawed as score components were assessed by self-report. Finally, the number of social dimensions and associated characteristics that could be investigated was limited in this study because the sample had to contain enough cases per intersectional stratum. To further take advantage of the strengths of the MAIHDA approach, future studies that can rely on larger case numbers should also consider other potentially diabetes-related social determinants, such as area level deprivation or living arrangements.

Conclusions

Mapping social disparities in the risk of developing type 2 diabetes, we found substantial differences in diabetes risk in Germany based on social position. These differences in diabetes risk seem to be primarily explained by additive main effects of the social dimensions that define social position, particularly sex/gender and education level, rather than intersectional effects. Therefore, to address the identified disparities in diabetes risk, it is recommended to implement targeted prevention measures adjusted to the needs of groups at increased risk, such as men and individuals with low educational level. To this end, further research on social inequality in relation to type 2 diabetes should explore underlying processes and intersectional patterns to inform effective prevention measures and reduce the risk of type 2 diabetes in vulnerable populations.

Abbreviations

BZgA: German Federal Centre for Health Education; CASMIN: Comparative Analysis of Social Mobility in Industrial Nations; DIfE: German Institute of Human Nutrition Potsdam-Rehbrücke; GDRS: German Diabetes Risk Score; ICC: Intraclass correlation; MAIHDA: Multilevel analysis of individual heterogeneity and discriminatory accuracy; PCV: Proportional change in variance; REML: Restricted maximum likelihood; RKI: Robert Koch Institute; VPC: Variance partition coefficient

Declarations

Acknowledgements

The authors would like to thank all participants of the survey ‘Disease knowledge and information needs – Diabetes mellitus (2017)’ for taking part.

Authors' contributions

FF, JLOS, EAP and PG conceptualized the study. CH, YD, and PG made contributions to the concept and design of the survey. FF prepared and analysed the data and EAP supported statistical analyses. JLOS supervised the study. All authors were involved in reviewing and interpreting the findings. FF was the main contributor in writing the manuscript. All authors reviewed and revised the current manuscript for submission. All authors read and approved the final manuscript.

Funding

The project "Gender-specific prevention of type 2 diabetes and health promotion (Prev*Diab)" is funded by the Federal Ministry of Health. Funding Code: 2520FSB114.

The survey "Disease knowledge and information needs – Diabetes mellitus (2017)" was funded by the Federal Ministry of Health. Funding Code: GE20160358.

Availability of data and materials

The authors confirm that some access restrictions apply to the analytical data set underlying our current findings. First, informed consent from the survey participants did not cover public deposition of data. Second, publicly providing an anonymized version of the analytical data set used in our current analysis would not comply with current data protection regulations in Germany, as anonymized information could still be used in combination to identify survey participants. Thus, the analytical data set underlying the findings is archived in the Research Data Centre at the Robert Koch Institute (RKI) and can only be accessed on-site by interested researchers at the Secure Data Center of the RKI's Research Data Centre. Requests should be submitted to the RKI Research Data Centre, Robert Koch Institute, Berlin, Germany (e-mail: fdz@rki.de).

Ethics approval and consent to participate

The "Disease knowledge and information needs – Diabetes mellitus (2017)" survey was approved by the ethics committee of the Berlin Chamber of Physicians in August 2017 (Ärztekammer Berlin; No. Eth-23/17) and the Federal Commissioner for Data Protection and Freedom of Information. Prior to the actual telephone interview, all participants were informed about study aims and procedure, the voluntary nature of their participation, as well as data protection regulations, and gave verbal informed consent to participate.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Figures

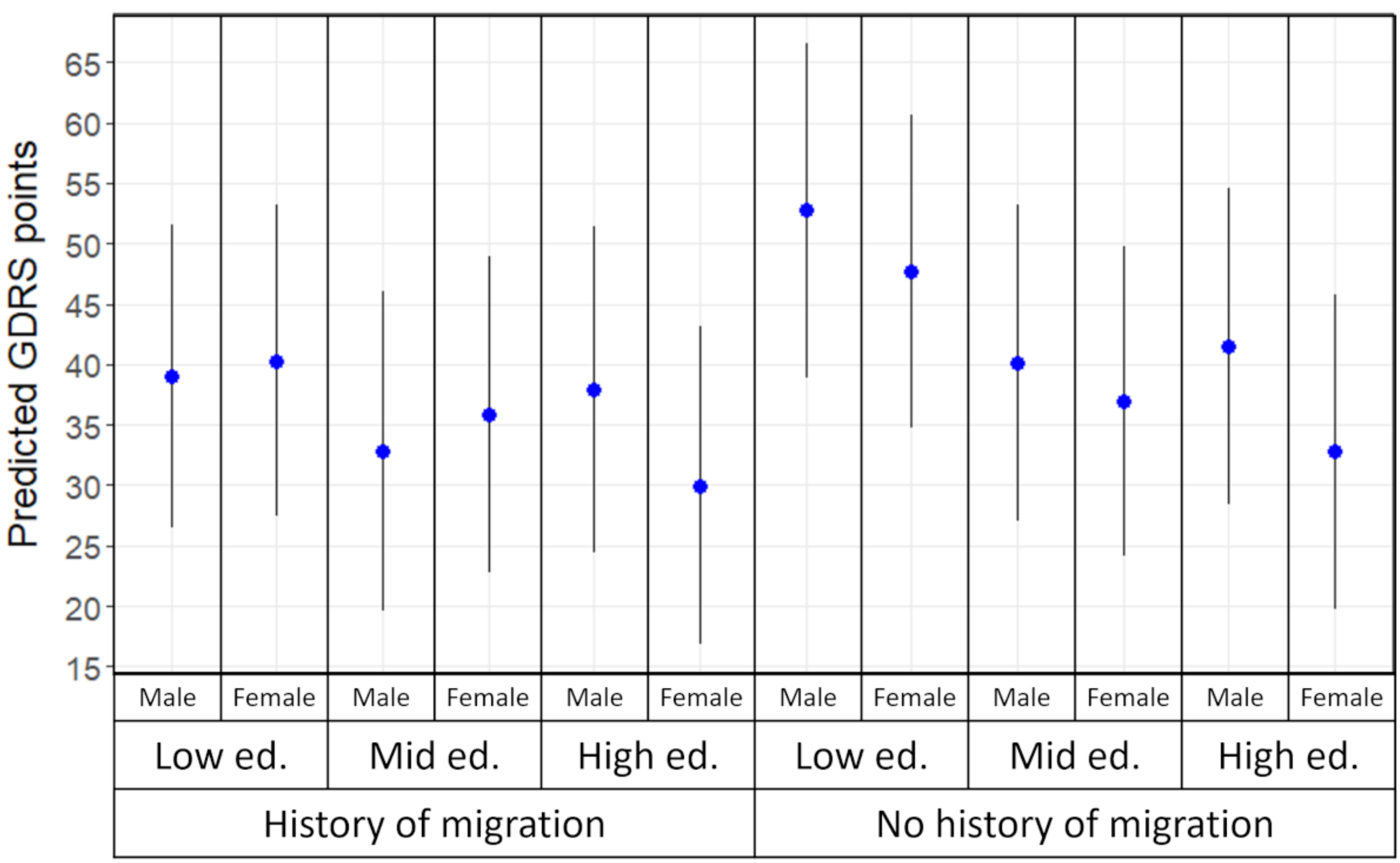

Figure 1

Stratum-specific predicted GDRS points with 95% confidence intervals obtained from model 1. ed.: educational level

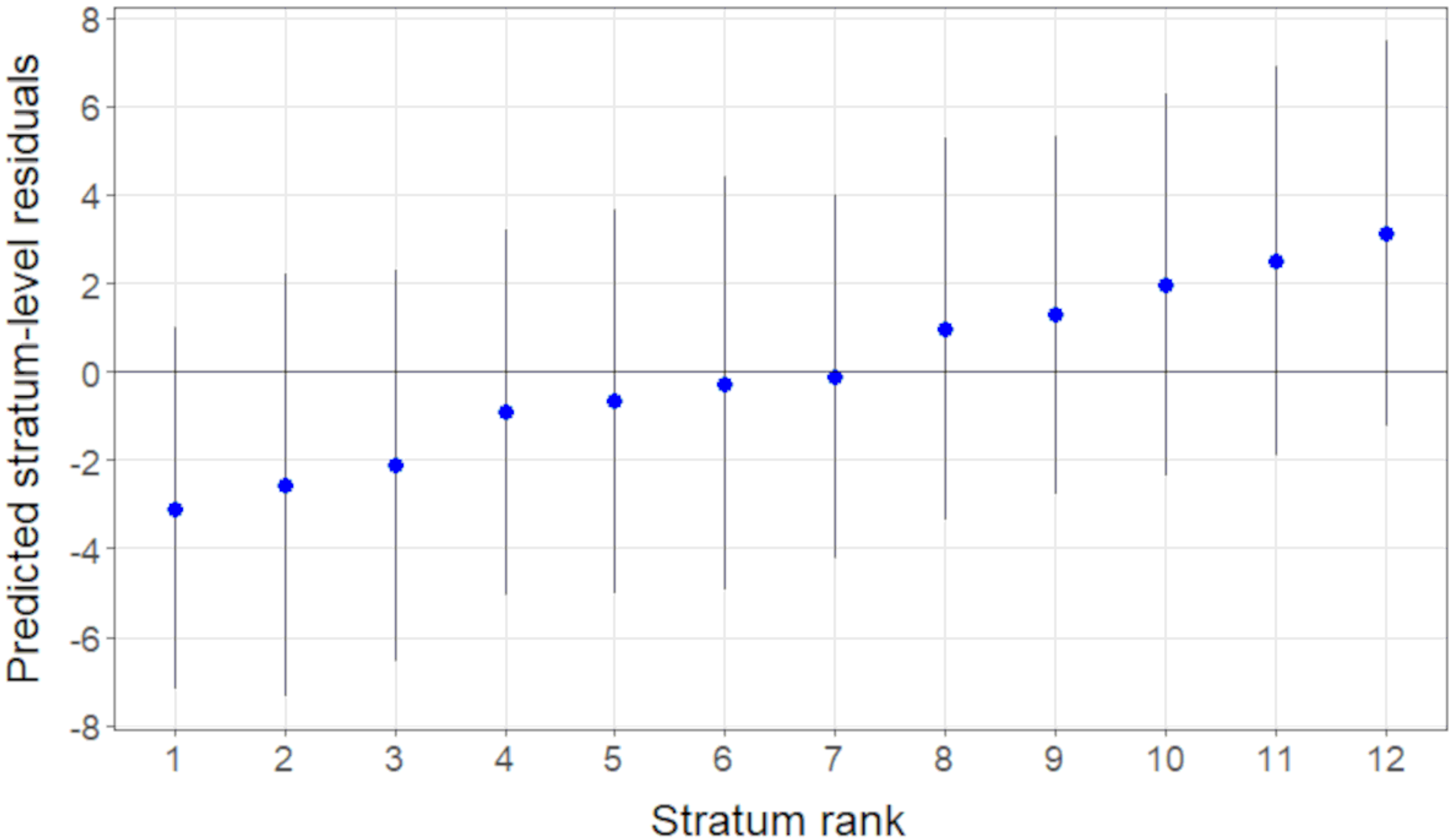

Figure 2

Predicted stratum-level residuals regarding GDRS with 95% confidence intervals obtained from model 2. Stratum ranks were 1 women with high educational level and no history of migration, 2 men with low educational level and history of migration, 3 men with middle educational level and history of migration, 4 men with middle educational level and no history of migration, 5 women with high educational level and history of migration, 6 women with low educational level and history of migration, 7 women with middle educational level and no history of migration, 8 women with low educational level and no history of migration, 9 men with high educational level and no history of migration, 10 men with low educational level and no history of migration, 11 men with high educational level and history of migration, 12 women with middle educational level and history of migration.

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