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Health Inequalities

Sex differences in the associations of socioeconomic status with undiagnosed diabetes mellitus and impaired glucose tolerance in the elderly population: the KORA Survey 2000

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Background: Sex differences in the associations of socioeconomic status (SES) with prevalence of undiagnosed diabetes mellitus, impaired glucose tolerance (IGT) and known risk factors of type 2 diabetes mellitus were investigated in an elderly population. **Methods:** Oral glucose tolerance tests were carried out in 1354 randomly selected subjects (697 men, 657 women) aged 55–74 years in the population-based KORA Survey 2000, Augsburg, Germany. Odds ratios (ORs) and 95% confidence intervals (CIs) for undiagnosed diabetes or IGT by education, occupation and income were estimated using logistic regression controlling for age, waist circumference, blood pressure, triglycerides, physical activity, smoking and alcohol intake. **Results:** All three SES variables were significantly inversely related to body mass index, waist circumference and low physical activity in women ($P < 0.05$). In men, these associations were weaker or absent. Using the lowest category as reference, occupational status was significantly associated with undiagnosed diabetes in women (adjusted OR 0.5; 95% CI 0.3–0.8) after controlling for risk factors in multivariate regression. The OR was also reduced with higher income in women (adjusted OR, diabetes: 0.7; 95% CI 0.5–1.03). Among men, no significant relations of the SES indicators with unknown diabetes were observed. However, the odds of having IGT was lower with higher occupational status in men (adjusted OR 0.7; 95% CI 0.5–0.9). **Conclusions:** Undiagnosed type 2 diabetes was related to low SES defined by occupation or income in women only. In men, low occupational status was independently associated with higher IGT risk. Educational level was not related to glucose disorders in both sexes in the elderly population.

Keywords: diabetes mellitus, impaired glucose tolerance, obesity, socioeconomic status

Socioeconomic status (SES) is inversely associated with the prevalence of type 2 diabetes mellitus in industrialized countries including the USA,[1–3] Canada,[4–6] the UK,[7–11] Sweden,[12] The Netherlands[13] and Germany.[14,15] This relationship has also been found in specific ethnic groups with high diabetes risk.[16,17] Furthermore, the risk of developing diabetes over time was related to SES.[18] The association between social circumstances and risk factors of type 2 diabetes, i.e. insulin resistance, may start in childhood.[19,20] Although in most populations only half of all cases are diagnosed, the majority of these studies were based on self-reports and thus did not differentiate between known and previously unknown diabetes.[21]

The health impact of social status may not be the same in men and women. Only a few studies have assessed sex differences in the relationship between SES and diabetes.[1,4,16] In national surveys in the USA and Canada, SES was more closely associated with diabetes in women than in men.[1,4] The pathways by which SES may differently affect the development of type 2 diabetes in men and women are unclear.[1]

Currently, only one study has investigated the relationship between SES and impaired glucose tolerance (IGT), and reported no significant association.[22] IGT is a risk factor for type 2 diabetes and coronary heart disease.[23] Obesity, the major predictor of IGT and type 2 diabetes, is more prevalent in groups of lower SES, in particular, among women.[24]

The impact of abdominal obesity, which is closely linked with insulin resistance, on the association between SES and glucose intolerance has rarely been studied.[25–27]

In order to fill some of these gaps, the aims of this study were to assess the sex-specific associations of SES, defined by education, occupation and income, with undiagnosed diabetes, IGT and known risk factors of type 2 diabetes mellitus, using data from a population-based survey in Augsburg, Germany.

Methods

Study population

The KORA Survey 2000 (KORA: Cooperative Health Research in the Region of Augsburg) is a population-based study in Southern Germany using the same region and methods as the WHO MONICA project.[28] Subjects were invited to participate from the city of Augsburg and 16 towns and villages out of 70 communities from the surrounding districts, which had about 600 000 inhabitants in 1999. Within each selected community, a

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stratified sample with 10 equal strata by gender and age was drawn; four of these strata included male and female subjects aged 55–74 years (two-stage cluster sampling).

Overall, 1653 (62%) of 2656 subjects aged 55–74 years participated. Non-participants ($n = 911$) were either too ill to come to the study centre ($n = 145$), had no time to attend investigations ($n = 78$) or were in general unwilling to participate ($n = 651$) despite enormous efforts to increase participation rate. After excluding 131 participants with known diabetes and further drop-outs, which were mainly persons who were not able to attend the fasting investigation during morning hours [non-fasting, $n = 158$; technical problems, $n = 8$; vomiting during oral glucose tolerance tests (OGTT), $n = 2$; missing 2 h glucose, $n = 1$], 1354 subjects had an OGTT.[28]

Fasting OGTTs were performed after informed consent in participants aged ≥55 years without known diabetes from October 1999 to April 2001. Standardized OGTT conditions were used to reduce measurement variation.[28] Study participants were asked to fast at least 8 h before the OGTT and to avoid unusual physical activity (sports) on the day before the test. Furthermore, they should not smoke prior to or during the OGTT. Glucose tolerance was not tested in cases of acute infections (fever) or any acute gastrointestinal problems, in particular, vomiting or diarrhoea. OGTT were not performed after 11:00 a.m. Tests were carried out by trained and quality-certified study nurses only. Newly diagnosed diabetes and IGT were defined according to the 1999 WHO criteria.[29]

Definitions of SES variables

Items related to SES were assessed in a structured health interview performed by trained investigators. Education was classified based on the highest level obtained: primary (Hauptschule, Volksschule), secondary (Mittlere Reife, Realschule) and tertiary (Abitur, Fachhochschulreife, Universität) education. Codes concerning occupations were extracted from an index proposed by Helmert and Shea[30] for German studies, as this code provides a good method for grouping different occupations according to a social class hierachy. According to the self-reports, three groups were categorized that reflect job position. For retired persons, the most recent occupation was coded. Among persons without regular employment (e.g. housewives), the occupation of the spouse was used as a proxy. Income was based on the total household net income, weighted by the number of household members in different age groups (i.e. equivalent household income). Income was classified into five groups according to the median income in the study population (<50%, 50–100%, 101–150%, 151–200% and >200% of the median income).

Anthropometric measurements and behavioural variables

Body weight was measured in light clothing to the nearest 0.1 kg and height to the nearest 0.5 cm. Waist circumference was measured at the maximum abdominal girth to the nearest 0.1 cm. Blood pressure was measured in a sitting position three times at the right arm after 15 min rest using an automatic device (OMRON HEM 705-CP). Means of the second and third measurement were included in the analysis.

In the structured interview, medical history was obtained including health-care utilization. Subjects were also asked to report the frequency and average duration of regular moderate and vigorous physical activity during leisure time in winter and summer using four categories. Less than 1 h activity per week was defined as low physical activity. Alcohol intake was assessed for the previous workday and the previous weekend. Increased intake was defined as >40 g per day in men and >20 g per day in women. Current smoking was defined as at least one cigarette per day on a regular basis.

Laboratory measurements

Blood glucose was measured using a hexokinase method (Gluco-quant; Roche Diagnostics, Mannheim, Germany). High-density lipoprotein (HDL) cholesterol was assessed using the phosphotungstic acid method (Boehringer Mannheim). Triglycerides were measured with the Boehringer GPO-PAP assay.[28]

Statistical analysis

Analyses were carried out separately for men and women, accounting for sampling weights and clustering (Stata Statistical Software, release 7.0; StataCorp, College Station, TX, USA). Descriptive analyses were obtained for all variables and differences between men and women were assessed using Student's t-test or χ^2-tests. Sex differences in SES indicators were evaluated using linear regression models including ordinal SES variables. Means [standard deviation (SD)] for normal distributed and geometric means (SD factor) for log-normal distributed continuous variables, or proportions for categorical variables, were calculated among the SES groups. Age-adjusted trends were evaluated using linear or logistic regression models. Prevalence of newly diagnosed diabetes and IGT in the various SES groups were calculated. Age-adjusted trend tests for diabetes and IGT were carried out by including ordinal variables for SES in logistic regression models. Finally, the associations of education, occupation and income with newly diagnosed diabetes or IGT were assessed using logistic regression models. SES indicators were included as dichotomous variables using the lowest class as reference (for income the lowest two classes). Age and fully adjusted models were fitted including potential risk factors. The level of significance was 5%.

Results

Characteristics of study participants

Demographic and behavioural characteristics, and risk factors among male and female survey participants are shown in table 1. Waist circumference, blood pressure and triglyceride concentrations were higher and HDL cholesterol was lower among men than women, indicating a more severe risk factor profile ($P < 0.05$). Low physical activity was found in >50% of both men and women ($P \geq 0.05$). Current smoking and increased alcohol intake was more often reported in men, whereas no significant sex differences were observed for self-reported health-care utilization (hospitalizations and physician visits) (table 1).

The distribution of SES indicators is shown in table 1. Significant sex differences were found for educational level, occupational status and income, which were all lower among women ($P < 0.05$). In both men and women, there was a skewed distribution of educational levels, with about 70% in the lowest group, as expected for this elderly population. In the age group aged 55–64 years, 39.8% of male and 32.6% of female survey participants were already retired.

After excluding all subjects with known diabetes, 10.6% of men and 7.5% of women had previously undiagnosed diabetes based on the OGTTs. Furthermore, the prevalence of IGT did not differ between men (18.5%) and women (17.3%).

SES and risk factors of type 2 diabetes

The distribution of various risk factors by SES are shown in table 2. In men, a significant inverse relation between body mass index (BMI) and education was found ($P < 0.05$), whereas no association was observed with waist circumference and physical activity ($P > 0.05$). Current smokers were more frequently found in the lowest educational category in men ($P < 0.05$). No significant relation with education was found for blood

Table 1 Characteristics of male and female survey participants without previously known diabetes mellitus aged 55–74 years: KORA Survey 2000, Augsburg, Germany

	Men (n = 697)	Women (n = 657)	P values
Age (years)	63.4 ± 5.8	63.8 ± 5.1	0.21
BMI (kg/m^2)	28.1 ± 3.8	28.5 ± 4.4	0.20
Waist circumference (cm)	100.2 ± 9.9	90.3 ± 10.4	<0.01
Systolic blood pressure (mmHg)	139.0 ± 20.3	130.8 ± 18.7	<0.01
Diastolic blood pressure (mmHg)	82.0 ± 10.9	78.0 ± 9.5	<0.01
HDL cholesterol (mmol/l)	1.4 ± 0.4	1.7 ± 0.4	<0.01
Triglycerides (mmol/l)	1.4 (1.7)	1.2 (1.5)	<0.01
Low physical activity (%)[a]	59.7	53.4	0.07
Smoker (%)	17.8	10.8	<0.01
Increased alcohol intake (%)[b]	21.3	11.3	<0.01
Hospitalization last 12 months (%)	16.6	14.3	0.11
Physician visit last 4 weeks (%)	41.3	46.6	0.07
Education level			
Primary	66.8 (62.5–71.1)	72.2 (65.4–79.1)	<0.01
Secondary	15.2 (12.1–18.3)	20.9 (15.4–26.5)	
Tertiary	18.0 (13.6–22.4)	6.8 (4.9–8.8)	
Occupational status[c]			
1 (low)	33.0 (28.5–37.5)	50.0 (45.4–54.6)	<0.01
2	35.6 (32.7–38.6)	35.3 (29.7–40.8)	
3 (high)	31.4 (27.9–34.8)	14.7 (10.4–19.1)	
Income[d]			
1 (low)	8.7 (4.5–12.9)	11.4 (5.5–17.2)	<0.01
2	47.9 (43.9–51.9)	48.6 (43.4–53.8)	
3	19.5 (15.8–23.3)	24.3 (20.0–28.7)	
4	17.6 (14.9–20.3)	11.8 (9.0–14.5)	
5 (high)	6.3 (4.4–8.2)	3.9 (2.4–5.4)	

Data are sample design-based means ± SD, geometric mean and SDF (triglycerides) or proportions (95%CI)
P values: age-adjusted differences between men and women
a: defined as <1 h/week moderate or vigorous physical activity
b: defined as ≥40 g alcohol/day in men and ≥20 g alcohol/day in women
c: three groups were categorized according to the self-reports. In persons without regular employment (e.g. housewives) the occupation of the spouse was used
d: income was based on the total household net income divided by the number of household members. Income was classified into five groups according to the median income in the study population (<50%, 50–100%, 101–150%, 150–200% and >200% of the median income)

pressure, serum lipids and health-care use in men (data not shown).

Occupational status yielded a significant inverse association with low physical activity in men (table 2). A similar relation was found with current smoking (both $P < 0.05$). Income also showed an inverse relationship with less physical activity in men ($P < 0.05$). Increased alcohol intake was most frequently reported in the highest income groups among male participants ($P < 0.01$). No significant SES differences were found for parental diabetes history in men (e.g. education: low, 20.4%; medium, 23.1%; high, 23.0% subjects with parental diabetes; $P = 0.72$).

In women, the associations of SES with body weight and physical activity were stronger than among men. A decrease of BMI, waist circumference and low physical activity with higher status was found for all three SES indicators ($P < 0.05$) (table 2). Using the 80th sex-specific percentiles for waist circumference among normal glucose-tolerant subjects as cut-off (men >109 cm; women >100 cm), the associations of SES indicators with abdominal adiposity were also stronger among women than men. Significant trends for abdominal obesity were found for all three SES indicators among women but not in men ($P < 0.01$). Current smoking also varied among the SES groups; however, there was no clear trend. Alcohol intake showed the highest prevalence in women with highest education ($P < 0.05$).

Whereas blood pressure was inversely related to education and occupation in women ($P < 0.05$), lipids did not significantly vary with SES indicators, except for HDL cholesterol and occupation (increase with higher status) ($P < 0.05$). Similar to men, no association of SES indicators with health-care utilization or parental diabetes history was found (all data not shown).

Table 2 The distribution of risk factors of type 2 diabetes by SES in men and women aged 55–74 years: KORA Survey 2000, Augsburg, Germany

	Education			Occupation (1 = low)			Income (1 = low)				
	Primary	Secondary	Tertiary	1	2	3	1	2	3	4	5
Men											
BMI (kg/m^2)	28.3*	27.9*	27.4*	28.3	28.0	28.0	28.0	28.0	28.0	28.4	28.2
Waist circumference (cm)	100.6	99.2	99.5	100.6	99.9	100.1	100.9	99.9	99.8	100.7	100.4
Low physical activity (%)	63.5	48.5	55.0	70.1*	54.2*	54.6*	78.7*	60.1*	55.3*	59.6*	45.4*
Smoker (%)	19.8*	12.7*	13.8*	24.0*	16.7*	12.2*	20.7	18.6	13.0	17.8	10.8
Increased alcohol intake (%)	19.4	26.7	23.6	19.4	21.4	22.7	22.7*	16.5*	22.2*	29.1*	30.8*
Women											
BMI (kg/m^2)	29.2*	26.8*	26.3*	29.4*	27.5*	27.9*	29.6*	29.0*	27.6*	27.9*	26.2*
Waist circumference (cm)	91.6*	86.8*	86.5*	92.1*	88.5*	87.8*	92.1*	91.3*	89.2*	87.6*	86.1*
Low physical activity (%)	57.3*	43.6*	43.0*	60.6*	42.8*	47.2*	67.3*	56.1*	44.0*	47.0*	37.1*
Smoker (%)	9.3	16.2	9.4	7.3*	16.8*	8.3*	1.5	12.9	11.1	12.8	14.9
Increased alcohol intake (%)	9.4*	15.7*	18.1*	8.6	15.3	11.9	11.2	9.9	10.2	18.4	22.0

*$P < 0.05$: test for trend, adjusted for age (linear or logistic regression models)
Data and tests are sample design-based

Table 3 Prevalence for newly diagnosed diabetes mellitus (NDM) and IGT according to SES in male and female survey participants aged 55–74 years: KORA Survey 2000, Augsburg, Germany

	Men				Women			
	NDM (%)	*P* value	IGT (%)	*P* value	NDM (%)	*P* value	IGT (%)	*P* value
Education								
Primary	10.5		18.3		9.1		16.6	
Secondary	11.4		22.8		2.8		19.8	
Tertiary	10.5	0.88	15.6	0.81	4.2	0.31	17.8	0.41
Occupational status								
1 (low)	13.4		21.9		10.0		20.4	
2	9.8		17.4		6.4		15.9	
3 (high)	8.8	0.28	16.4	0.08	1.2	0.01	13.3	0.08
Income adequacy								
1 (low)	6.6		19.7		5.8		21.4	
2	11.5		20.0		9.7		15.4	
3	9.9		11.0		5.9		18.9	
4	10.7		21.8		2.9		19.6	
5 (high)	11.8	0.55	20.7	0.66	12.3	0.59	7.5	0.73

**P* value: age-adjusted test for trend (logistic regression models) in men or women
Prevalence and regression models are sample design-based

SES indicators and glucose tolerance groups

Prevalence of newly diagnosed diabetes and IGT according to socioeconomic indicators are shown in table 3. The relationship between occupation and newly diagnosed diabetes or IGT was inverse and graded in both sexes; however, this was only statistically significant for diabetes in women ($P = 0.01$). In both men and women, a borderline significance was found for occupation and IGT ($P = 0.08$).

For education, no trends for newly diagnosed diabetes or IGT were found in either sex. Prevalence of newly diagnosed diabetes and IGT also varied within the income groups in men and women; however, no systematic variation could be found.

Multivariate associations of SES with glucose tolerance groups

In women, a significantly reduced risk of undiagnosed diabetes was found with higher occupational status, which was unchanged after adjusting for risk factors [odds ratio (OR) 0.5; 95% confidence interval (CI) 0.3–0.9]. Also, for income a borderline significance was found (adjusted OR 0.7; 95% CI 0.5–1.03). Education was not significantly associated with unknown diabetes in female participants, although the point estimate of the OR was well below 1.0.

In women, separate models for occupation were also fitted after excluding all participants without regular employments (e.g. housewives) ($n = 87$). The point estimates of the ORs were similar to the whole sample; however, they were no longer statistically significant owing to the lower sample size (data not shown).

In men, no significant associations of education, occupation or income with newly diagnosed diabetes were found in the multivariate models (table 4).

With respect to IGT, higher occupational status yielded a significant inverse association with IGT in men, which persisted after adjusting for confounders ($P < 0.05$). Education and income were not related to the odds of having IGT in male participants (table 4).

In women, no significant associations of occupation or income with IGT were found, whereas there was increased risk for IGT with higher education in the multivariate model using primary education as baseline (OR 1.6; 95% CI 1.2–2.3).

Discussion

In the KORA Survey 2000, a strong inverse association between SES, defined by occupation, and the odds of having undiagnosed diabetes was found in women aged 55–74 years. There was also an indication for an increased risk of unknown diabetes in women with lower income. In men, no significant relations between these SES indicators and undiagnosed diabetes were found. However, risk of IGT was increased in men with low SES (occupation) even after controlling for obesity, low physical activity and other risk factors.

Sex differences in the risk of known diabetes and SES have been reported previously.[1,4] In the Third National Health and Nutrition Examination Survey, SES was significantly associated with type 2 diabetes in both African-American and white women, whereas no relationship was found for men.[1] In the National Population Health Survey in Canada, low income and education remained significantly associated with self-reported diabetes after controlling for BMI and physical activity in women.[4] In men, the associations were weaker and did not persist after controlling for risk factors.

The reasons for sex differences in the association of SES with type 2 diabetes are unclear. Unhealthy behaviour, unequal access to health care, nutritional factors, psychological stress, depression, or pre- and perinatal environmental factors have been proposed as possible mechanisms linking SES to diabetes.[1,18] Lower social class in childhood was associated with increased insulin resistance in later life, the hallmark of type 2 diabetes.[19,20] Low socioeconomic position in childhood was also related to increased prevalence of obesity in adulthood, even after adjusting for adult social class.[19] Effect modification by sex in the association between SES and obesity was found in several studies, being stronger in women than in men.[24] It is noteworthy, that in the present analysis, an inverse association of all three SES indicators with waist circumference or abdominal adiposity was found in women only. Abdominal adiposity is a central hallmark of the insulin resistance syndrome.[25] Physical inactivity is another major behavioural risk factor of type 2 diabetes. Women with higher SES are more physically active than women with low SES, whereas this social gradient may be less pronounced in men.[14,31]

In line with previous investigations, health-care utilization was not related to SES and undiagnosed diabetes in the present study.[1] However, only the uptake of health care services was assessed, and not what providers did if the system was accessed.[21]

Table 4 ORs (95% CI) for prevalence of newly diagnosed diabetes or IGT in men and women aged 55–74 years in relation to SES: KORA Survey 2000, Augsburg, Germany

	Men		Women		Men		Women	
	Diabetes, age-adjusted[a]	Diabetes, fully adjusted[b]	Diabetes, age-adjusted[a]	Diabetes, fully adjusted[b]	IGT, age-adjusted[a]	IGT, fully adjusted[b]	IGT, age-adjusted[a]	IGT, fully adjusted[b]
Education: secondary versus primary	1.1 (0.6–1.8)	1.2 (0.7–1.9)	0.3 (0.1–1.8)	0.3 (0.1–1.7)	1.1 (0.7–1.6)	1.1 (0.7–1.6)	1.2 (0.9–1.7)	1.6 (1.2–2.3)*
Occupation: 2nd level[c] versus 1st level	0.7 (0.3–1.4)	0.7 (0.4–1.4)	0.5 (0.3–0.9)*	0.5 (0.3–0.9)*	0.7 (0.5–0.98)*	0.7 (0.5–0.93)*	0.7 (0.5–1.02)	0.9 (0.6–1.3)
Income: 3rd level[d] versus 1st and 2nd level	1.0 (0.6–1.8)	1.1 (0.7–1.9)	0.6 (0.4–1.02)	0.7 (0.5–1.03)	0.9 (0.6–1.3)	0.8 (0.5–1.3)	1.1 (0.7–1.9)	1.4 (0.8–2.3)

a: sample design-based logistic regression model adjusted for age only; $*P < 0.05$
b: adjustment for age, waist circumference, physical activity, systolic and diastolic blood pressure, triglycerides, smoking, and alcohol intake
c: three groups were categorized according to the self-reports. In persons without regular employment (e.g. housewives) the occupation of the spouse was used
d: income was based on the total household net income weighted by the number of household members in different age groups. Income was classified into five groups according to the median income in the study population (<50%, 50–100%, 101–150%, 150–200% and >200% of the median income)

Prevalence of IGT was inversely related to occupational status in men in the KORA survey. Furthermore, higher education was significantly associated with an increased risk of IGT in women. This was an unexpected finding, in particular because education was not significantly related to diabetes risk. In a previous study among Hong Kong Chinese, no significant relationship between SES, defined by education and occupation, and IGT was found.[22] However, the study was based on a sample with high diabetes risk, mainly comprising women.[23] IGT refers to an intermediate metabolic state between normal glucose tolerance and diabetes, and not all subjects with IGT will progress to manifest type 2 diabetes.[23,29]

Thus, the heterogeneity of persons with IGT most likely explains the different associations between SES and diabetes in the present study.

The KORA OGTT study included the age group 55–74 years because of their known increased risk of type 2 diabetes.[28] There is little information on the extent of health inequalities related to SES in elderly populations. Some studies have suggested that health inequalities decrease with increasing age,[32] but other studies have indicated that health inequalities are similar in all age groups.[33] In Germany, one study suggested that the extent of health inequalities in cardiovascular disease, which is closely related to type 2 diabetes, is relatively small in the age group 60–69 years.[34] Therefore, in the age-group included in the present study one would not expect as clear health inequalities as observed in younger age groups. Our results confirmed this expectation, as a mixed picture concerning the association with different SES variables was found. Special attention should be paid to the fact that different SES variables yielded different results. In the present study, health inequalities based on occupation were more pronounced than those based on income or education. In order to better disentangle the complex picture, it can be recommended that different SES variables should be used and compared in future studies.

Several limitations of this study need to be considered. Despite enormous efforts, the participation rate in the KORA Survey was only 62%, which may have introduced selection bias related to SES. Furthermore, it might be considered as drawback that subjects with known diabetes were not included. However, the selection of newly diagnosed type 2 diabetes allowed us to study the association with SES among incident cases. Subjects with known diabetes reflect determinants of development as well as duration of the disease. It is conceivable that in some patients with long-standing diabetes and severe disabling diabetic complications, poor health may result in low SES. Furthermore, residential area and housing tenure as aspects of SES were not included in the study because the study area is rather homogeneous in this respect. There are only small areas with markedly differing residential characteristics and only few participants would be expected to come from those areas.

In conclusion, undiagnosed diabetes was related to low SES in women. This association was most pronounced if SES is measured by occupational status. Known risk factors for type 2 diabetes may only partly explain this relation. In men, no significant associations between SES indicators and unknown diabetes were found. However, a significantly increased risk of IGT was found in men with low SES even after controlling for obesity, physical activity and other risk factors. The influence of SES on the development of type 2 diabetes needs to be further investigated.

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Key points

- Although in most populations only half of all cases are diagnosed, the majority of studies on the association of socioeconomic status (SES) with type 2 diabetes did not differentiate between known and previously unknown diabetes.
- A strong inverse association between SES and the odds of having undiagnosed diabetes was found in women aged 55 to 74 years in the population-based KORA Survey 2000 (Augsburg, Germany).
- In men, no significant relations between SES indicators and undiagnosed diabetes were found, however, the prevalence of prediabetes (impaired glucose tolerance) was increased in men with low SES even after controlling for obesity, physical activity, and other risk factors.
- Any policy interventions to address type 2 diabetes screening and prevention in the elderly population need to take into account these socioeconomic inequalities.

References

1 Robbins JM, Vaccarino V, Zhang H, Kasl SV. Socioeconomic status and type 2 diabetes in African American and non-Hispanic white women and men: evidence from the Third National Health and Nutrition Examination Survey. *Am J Public Health* 2001;91:76–83.

2 Leonetti DL, Tsunehara CH, Wahl PW, Fujimoto WY. Educational attainment and the risk of non-insulin-dependent diabetes or coronary heart disease in Japanese-American men. *Ethn Dis* 1992;2:326–36.

3 Brancati FL, Whelton PK, Kuller LH, Klag MJ. Diabetes mellitus, race, and socio-economic status. A population-based study. *Ann Epidemiol* 1996;6:67–73.

4 Tang M, Chen Y, Krewski D. Gender-related differences in the association between socioeconomic status and self-reported diabetes. *Int J Epidemiol* 2003;32:381–5.

5 Choi BCK, Shi F. Risk factors for diabetes mellitus by age and sex: results of the National Population Health Survey. *Diabetologia* 2001;44:1221–31.

6 Green C, Hoppa RD, Young TK, Blanchard JF. Geographic analysis of diabetes prevalence in an urban area. *Soc Sci Med* 2003;57:551–60.

7 Marmot MG, Davey Smith G, Stansfield S, et al. Health inequalities among British civil servants: the Whitehall II study. *Lancet* 1991;337:1387–93.

8 Connolly V, Unwin N, Sherriff P, et al. Diabetes prevalence and socioeconomic status: a population based study showing increased prevalence of type 2 diabetes mellitus in deprived areas. *J Epidemiol Community Health* 2000;54:173–7.

9 Ismail AA, Beeching NJ, Gill GV, Bellis MA. Capture–recapture-adjusted prevalence rates of type 2 diabetes are related to social deprivation. *Q J Med* 1999;92:707–10.

10 Evans JM, Newton RW, Ruta DA, et al. Socio-economic status, obesity and prevalence of Type 1 and Type 2 diabetes mellitus. *Diabet Med* 2000;17:478–80.

11 Whitford DL, Griffin SJ, Prevost AT. Influences on the variation in prevalence of type 2 diabetes between practices: practice, patient or socioeconomic factors? *Br J Gen Pract* 2003;53:9–14.

12 Hjelm K, Isacsson A, Apelqvist J, et al. Foreign and Swedish-born diabetic patients—a population-based study of prevalence, glycaemic control and social position. *Scand J Soc Med* 1996;24:234–52.

13 Mackenbach JP, Looman CW, van der Meer JBW. Differences in the misreporting of chronic conditions, by level of education: the effect on inequalities in prevalence rates. *Am J Public Health* 1996;86:706–11.

14 Knopf H, Ellert U, Melchert HU. Social strata and health (in German). *Gesundheitswesen* 1999;61:S169–77.

15 Helmert U, Janka HU, Strube H. Epidemiologische Befunde zur Häufigkeit des Diabetes mellitus in der Bundesrepublik Deutschland 1984 bis 1991. *Diab Stoffw* 1994;3:271–7.

16 Stern MP, Rosenthal M, Haffner SM, et al. Sex differences in the effects of sociocultural status on diabetes and cardiovascular risk factors in Mexican Americans. *Am J Epidemiol* 1984;120:834–51.

17 Cuasay LC, Lee ES, Orlander PP, et al. Prevalence and determinants of type 2 diabetes among Filipino-Americans in the Houston, Texas Metropolitan Statistical Area. *Diabetes Care* 2001;24:2054–8.

18 Everson SA, Maty SC, Lynch JW, Kaplan GA. Epidemiologic evidence for the relation between socio-economic status and depression, obesity and diabetes. *J Psychosom Res* 2002;53:891–5.

19 Lawlor DA, Ebrahim S, Davey Smith G. Socioeconomic position in childhood and adulthood and insulin resistance: cross sectional survey using data from British women's heart and health study. *BMJ* 2002;325:805–10.

20 Lawlor DA, Davey Smith G, Ebrahim S. Life course influences on insulin resistance: findings from the British Women's Heart and Health Study. *Diabetes Care* 2003;26:97–103.

21 McKinlay J, Marceau L. US public health and the 21st century: diabetes mellitus. *Lancet* 2000;356:757–61.

22 Ko GTC, Chan CN, Yeung VTF, et al. A low socio-economic status is an additional risk factor for glucose intolerance in high risk Hong Kong Chinese. *Eur J Epidemiol* 2001;17:289–95.

23 Unwin N, Shaw J, Zimmet P, Alberti KG. Impaired glucose tolerance and impaired fasting glycaemia: the current status on definition and intervention. *Diabet Med* 2002;19:708–23.

24 Wardle J, Waller J, Jarvis MJ. Sex differences in the association of socioeconomic status with obesity. *Am J Public Health* 2002;92:1299–304.

25 Brunner EJ, Marmot MG, Nanchahal K, et al. Social inequality in coronary risk: central obesity and the metabolic syndrome. Evidence from the Whitehall II study. *Diabetologia* 1997;40:1341–9.

26 Gaillard TR, Schuster DP, Bossetti BM, et al. The impact of socioeconomic status on cardiovascular risk factors in African-Americans at high risk for Type 2 diabetes. Implications for syndrome X. *Diabetes Care* 1997;20: 745–52.

27 Wamala SP, Lynch J, Horsten M, et al. Education and the metabolic syndrome in women. *Diabetes Care* 1999;22:1999–2003.

28 Rathmann W, Haastert B, Icks A, et al. High prevalence of undiagnosed diabetes mellitus in Southern Germany: target populations for efficient screening. The KORA Survey 2000. *Diabetologia* 2003;46:182–9.

29 Alberti KGMM, Zimmet PZ, for the WHO Consultation. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: Diagnosis and classification of diabetes mellitus. Provisional report of a WHO consultation. *Diabet Med* 1998;15:539–53.

30 Helmert U, Shea S. Social inequalities and health status in Western Germany. *Public Health* 1994;108:341–56.

31 Ford ES, Merritt RK, Heath GW, et al. Physical activity behaviors in lower and higher socioeconomic status populations. *Am J Epidemiol* 1991;133:1246–56.

32 Huisman M, Kunst A, Mackenbach J. Socioeconomic inequalities in morbidity among the elderly; a European overview. *Soc Sci Med* 2003;57:861–73.

33 Knesebeck O, Lueschen G, Cockerham W, Siegrist J. Socioeconomic status and health among the aged in the United States and Germany: A comparative cross-sectional study. *Soc Sci Med* 2003;57:1643–1652.

34 Helmert U, Maschewsky-Schneider U, Mielck A, Greiser E. Social inequality in myocardial infarct and stroke in West Germany (in German). *Soz Praventivmed* 1993;38:123–32.

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