BMJ Public Health

Exploring the gender difference in type 2 diabetes incidence in a Swiss cohort using latent class analysis: an intersectional approach

Jeanne Marie Barbier ,[1,2] Michael Amiguet ,[1] Julien Vaucher ,[2,3] Aurélie M Lasserre,[4] Carole Clair,[1] Joëlle Schwarz[1]

To cite: Barbier JM, Amiguet M, Vaucher J, *et al*. Exploring the gender difference in type 2 diabetes incidence in a Swiss cohort using latent class analysis: an intersectional approach. *BMJ Public Health* 2024;**2**:e000472. doi:10.1136/bmjph-2023-000472

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjph-2023-000472).

Received 4 August 2023
Accepted 17 January 2024

[1]Department of Ambulatory Care, Unisanté, Lausanne, Vaud, Switzerland
[2]Department of Medicine, Division of internal medicine, Lausanne University Hospital, Lausanne, Vaud, Switzerland
[3]Department of Medicine and Specialties, Fribourg hospital and University of Fribourg, Fribourg, Switzerland
[4]Department of Psychiatry, Lausanne University Hospital, Lausanne, Switzerland

Correspondence to
Dr Jeanne Marie Barbier; jeanne.barbier@chuv.ch

ABSTRACT

Introduction Type 2 diabetes is multifactorial and influenced by the intersection of gender-related variables and other determinants of health. The aim of this study was to highlight the intersectional social position of the participants and disentangle its role from administrative sex in predicting the development of type 2 diabetes.

Methods Using CoLaus|PsyCoLaus study, a Swiss single-centre prospective cohort initiated in 2003 and including 6733 participants (age 35–75 years; 54% women) at baseline, we conducted latent class analyses using gender-related variables (eg, risk-taking behaviours, gender roles represented by employment status, etc) and socioeconomic determinants at baseline (2003–2006) to construct intersectional classes and we tested their association with the development of type 2 diabetes at follow-up (2018–2021).

Results Of the 6733 participants enrolled at baseline, 3409 were included in our analyses (50.6%). Over a median follow-up time of 14.5 years, 255 (7.5%) participants developed type 2 diabetes, of which 158 men (62.0%). We identified seven latent classes highlighting different intersectional social position groups (ie, *young, fit, educated men (N=413), non-White physically inactive men and women (N=170), highly qualified men, former or current smokers (N=557), working women living alone (N=914), low qualified working men with overweight (N=445), women with obesity, low education and low qualified job or housewives (N=329), low educated retired participants (N=581)*). Using the class labelled as 'young, fit, educated men' as reference, the risk of incident type 2 diabetes was higher in all other classes (adjusted OR values between 4.22 and 13.47). Classes mostly feminine had a more unfavourable intersectional social position than that of the predominantly masculine classes. The corresponding OR increased in sex-adjusted regressions analyses.

Conclusions We observe cumulative intersectional effects across behavioural and socioeconomic profiles with different risks of developing type 2 diabetes emphasising the deleterious effect of a feminine gender profile. These patterns are only partly captured by traditional sex-stratified analyses.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Sex differences in epidemiology, treatment and outcomes of type 2 diabetes exist.
⇒ Environmental exposure and socioeconomic position differences lead to disparities in health and health-related behaviours and influence the clinical presentation, development and predisposition of type 2 diabetes.
⇒ Socioeconomic position and health-related behaviours are not equally distributed among women and men.

WHAT THIS STUDY ADDS

⇒ The intersectional social position influences the risk of developing type 2 diabetes beyond administrative sex and unfavourable intersectional social position among predominantly feminine classes emphasises a deleterious effect of the feminine gender profile.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The portion of risk attributable to the gender profile incorporating the notion of intersectionality, beyond the administrative sex, is to be included into prevention strategies and risk score development.

INTRODUCTION

In 2019, 9.3% of the adult population aged 20–79 years were living with type 2 diabetes worldwide[1] with a rapid prevalence increase in regions facing an epidemiological transition. Three major risk factor categories for type 2 diabetes are recognised: biological risk factors such as unfavourable genetic and epigenetic modifications (eg, related to maternal or paternal obesity) and hormonal status (eg, high testosterone levels in women or low sex hormone-binding globulin levels),[2 3] a low socioeconomic status[2 4 5] and cardiometabolic risk factors (eg, obesity,[6] smoking,[7] physical inactivity,[8] depression[9]).

In vivo, these categories are not mutually exclusive, and individuals find themselves at their intersections.[10]

Previous literature reported sex differences in type 2 diabetes epidemiology: worldwide and in high-income countries, men display an approximately 1-3-1.5-fold higher prevalence of type 2 diabetes than women.[11–13] In high-income Western countries in 2019, an age-standardised prevalence is of 7.3% in men and 5.3% in women,[14] although women are predominant among youth-onset diabetic patients.[3] Sex-disaggregated data on type 2 diabetes in Switzerland are scarce, but one study reported an age-adjusted prevalence of 7.8% in men and 5.7% in women.[11] Concerning socioeconomic status, women tend to have a less favourable position than men (eg, lower educational level and job qualification, more often living alone and/or raising children alone)[15 16] and their professional stress increased in the last decade.[17] Regarding exposure to cardiometabolic risk factors, women tend to display a more favourable cardiometabolic profile and healthier health-related behaviours patterns (eg, smoking, drinking alcohol, alimentation) than men.[15 18] Moreover, the probability of developing type 2 diabetes after cardiometabolic[2 19–21] and socioeconomic[4] risk factor exposition is higher for women and they have an excess risk of CVD compared with men exposed to the same risk factors,[2 3] supporting the hypothesis of women developing type 2 diabetes at worse metabolic states than men.[22] Nevertheless, available research on type 2 diabetes epidemiology mainly set hypotheses on sex differences a posteriori and study biological, cardiometabolic and socioeconomic risk factors separately failing to provide thorough explanations of the combined effects of these different categories.

Restricting research to the man/woman variable may be limiting as it entangles potential biological and social factors on one hand and prevents the integration of the other social dimensions and systemic power relations that modulate the intersectional social positions of women and men on the other hand. More precisely, intersectionality posits that *individual identities and social locations such as gender, race, and class intersect* and represents *unique experiences that are overlooked by focusing on one identity over another.*[23] We assume this conceptualisation of gender as one aspect of the social positions shaping the life experience of individuals. Gender medicine research has highlighted how gender influences risk exposure, health-related behaviours and access to healthcare.[24] It also defined three different levels of the gender dimension (ie, individual, interactional and institutional): as an example, risk-taking behaviours are proxy for the conformity to (masculine) gender norms on the individual level and job-related physical intensity for gender roles on the interactional level (figure 1). In recent years, this new focus on medical research challenged the sex dichotomy in how epidemiological science and knowledge are conceived and different research methods on how to integrate gender in clinical research are being developed.[24–28] The authors advocate for disentangling sex and gender, illustrating how neglecting gender in its predefined sense reinforces health disparities, and arguing for robust methods to improve the reproducibility of these emerging approaches. Nevertheless,

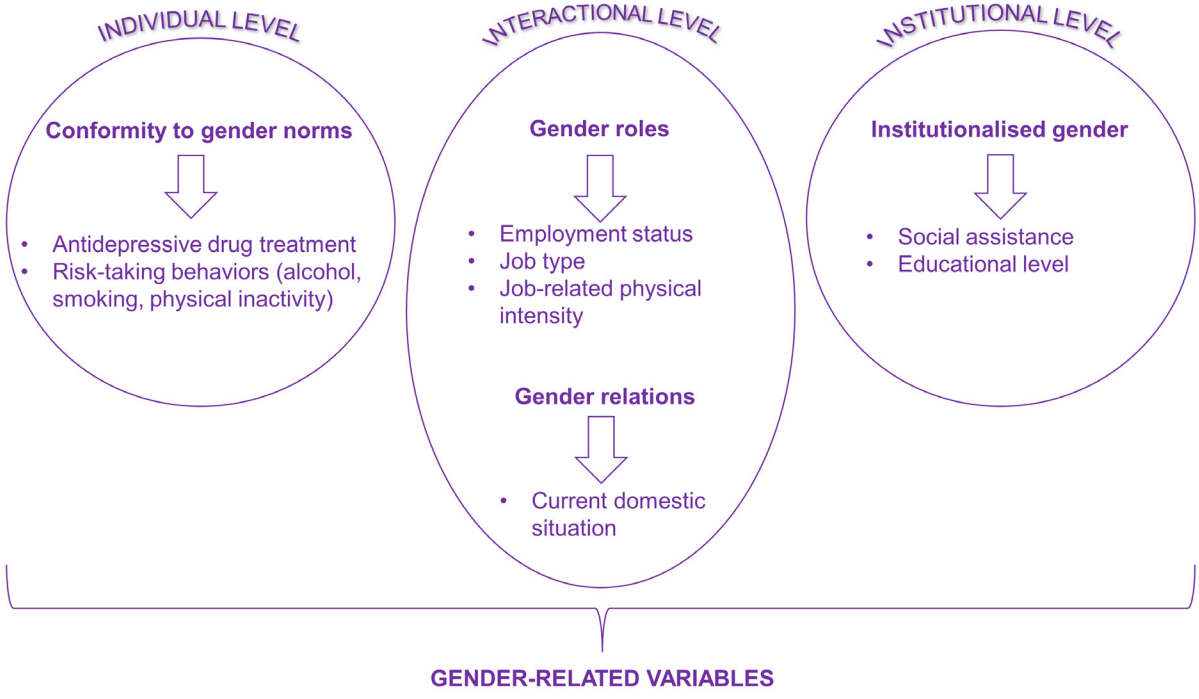

Figure 1 Gendered-related variables representing the three levels of the gender dimension.

operationalisation of gender as an intersectional sociological concept remains a challenge.[29] To the best of our knowledge, only a limited number of studies have delved into the multidimensional impact of gender on acute coronary syndrome[30] and, more recently, metabolic syndrome.[31]

The originality of this study is its contribution to explore the added value of a latent class analyses (LCA) approach to describe and understand the role of the intersectional social position (including multidimensional gender, sociodemographic and health-related behaviour variables) in contributing to the differences observed between women and men related to their risk of developing type 2 diabetes.

METHODS

Study design

This project is a data analysis of the CoLaus|PsyCoLaus study, a single-centre prospective cohort on determinants of cardiovascular and mental disease, initiated in 2003 in Lausanne, Switzerland. Its detailed protocol has been described previously.[15 32] Between 2003 and 2006, 6733 subjects (age range 35–75 years, 54% women) were randomly recruited from the population of Lausanne, located in the French-speaking part of Switzerland. Periodic resurveys of the whole cohort were conducted over an 18-year follow-up.

Patient and public involvement

No patient or public involvement in the study design.

Inclusion and exclusion criteria

The CoLaus|PsyCoLaus study initially included participants aged 35–75 who provided written informed consent and had French language ability. For this secondary analysis, exclusion criteria comprised baseline diabetes (type 1 or 2), missing information on diabetes at baseline, and missing information on diabetes at the third follow-up.

Definitions

Outcome definition

Incident type 2 diabetes was defined as having a fasting plasma glucose ≥7 mmol and/or reporting an antidiabetic drug treatment (ie, oral and/or parenteral) at third follow-up without fulfilling these criteria at baseline. Glycosylated haemoglobin (HbA1c) measurement was not available at baseline and, therefore not used as an outcome criterion.

Gender-related factors

Defining which variables available at baseline would be considered as gendered-related factors was based on the gender toolbox we developed[33] to represent the three levels of gender (individual, interactional and institutionalised). These variables were also expected to differ between men and women and to have an influence on health outcomes (ie, incidence of type 2 diabetes).[28]

At the individual level, conformity to gender norms (use of antidepressant drug treatment) and risk-taking behaviours (including alcohol consumption, smoking, physical inactivity) was selected. At the interactional level, gender roles (represented by employment status, current job type and job-related physical intensity) and gender relations (represented by current domestic situation) were selected. Receiving social help and educational level were selected to represent the institutionalised gender (ie, the institutional level) (figure 1).

Confounding factors

We considered cardiometabolic risk factors (age categories, cardiovascular disease at baseline, abdominal obesity, high blood pressure (BP), dyslipidaemia, familiar history of type 2 diabetes, polycystic ovary syndrome (PCOS), history of gestational diabetes and menopause status) and sex as confounding factors for regression analyses.

Data collection

Following an overnight fast, participants visited Lausanne University Hospital for a physical examination, a 50 mL blood sample, and an interview with a trained nurse.

The physical examination in light clothes and barefoot included measures of weight (in kilograms to the nearest 100 g using a Seca scale (Hamburg, Germany); height (to the nearest 5 mm using a Seca (Hamburg, Germany)) height gauge); waist circumference (ie, the average of two measurements executed midway between the lowest rib and the iliac crest), and BP (measured three times using an Omron HEM-907 (Matsusaka, Japan) automated oscillometric sphygmomanometer after at least a 10 min rest in a seated position). For BP, we used the average of the last two measurements.

Overweight was defined as body mass index (BMI) ≥25 and <30 kg/m^2 and obesity as BMI ≥30 kg/m^2. Abdominal obesity was defined as waist circumference >102 cm for men and >88 cm for women.[34]

Glucose, triglycerides and high-density lipoprotein (HDL)-cholesterol were measured with a Modular P apparatus (Roche Diagnostics, Switzerland) at the clinical laboratory of the Lausanne University Hospital within 2 hours of blood collection. Low-density lipoprotein (LDL)-cholesterol levels were assessed using the Friedewald formula. Low HDL-cholesterol was defined as HDL-cholesterol <1 mmol/L for men and <1.3 mmol/L for women; high-LDL was defined as LDL-cholesterol ≥3.4 mmol/L; hypertriglyceridemia was defined as triglycerides ≥1.7 mmol/L. High BP was defined as systolic BP ≥140 and/or diastolic BP ≥90 mm Hg and/or presence of an antihypertensive drug treatment. Dyslipidaemia was defined as low-HDL and/or high-LDL and/or hypertriglyceridemia and/or presence of a hypolipidemic drug treatment. Prescribed and over-the-counter medication was collected by questionnaire.

Demographic, cardiometabolic history and lifestyle data were gathered through a questionnaire, including information on adoption status and place of birth

(Switzerland or elsewhere). Other sociodemographic information retrieved were 'White' as self-reported race; current domestic situation (alone, monoparental family, couple living without children, couple living with children); education ('high' for university; 'middle' for secondary and high school; 'low' for compulsory education, apprenticeship or none); receiving social help (yes, no or does not know); current professional status ('working at least 50%', 'not working or working at ≤50%' or 'staying at home'); current job type ('high qualification' for entrepreneur, liberal profession and senior management; 'middle qualification' for independent worker, middle management and qualified worker; 'low qualification' for employed worker, farmer, unqualified worker, manoeuvre; 'not working') and job-related physical activity (sitting, standing, carrying light load, carrying heavy load). Baseline cardiovascular disease (ie, stroke and acute coronary syndrome history) was adjudicated. Positive family history of diabetes was noted if either parent had diabetes. Relevant gynaecologic pathologies (eg, PCOS, gestational diabetes, menopause status) were documented. Lifestyle data encompassed weekly alcohol consumption (considered at risk if ≥28 units for men, ≥14 units for women), smoking status (never, former, current) and physical activity (≥20 min two times per week).

Statistical methods

For all descriptive analyses, we reported categorical variables as frequency and percentage and continuous variables as mean (SD) for normally distributed data and median (IQR) for skewed data. We used independent samples t-tests (for continuous variables) and χ^2 tests (for categorical variables) to compare the distribution of baseline characteristics. We used non-parametric equivalent tests in non-normal distributions. We performed LCA, a finite mixture model identifying homogeneous groups in a diverse population using selected indicators.[35 36] Variables within each latent class are independent, resulting in consistent profiles across different categorical subgroups (eg, in men, women and all age categories in this study). We used a theory-driven approach and retained as class-defining indicators the gender-related variables mentioned above and BMI as it is strongly related to socioeconomic status and lifestyle[37] and cannot be reduced to a pure biological variable (online supplemental methods M1). We did not introduce the outcome (ie, incident type 2 diabetes cases) in the LCA design but indicators represented assumed determinants of its development. We fitted a series of latent class models starting from k=1 onward (where k represents the number of classes). We ensured that the smallest class size was >1.5% of the study sample as in previous research[38] and assigned each individual to the class for which he or she had the highest posterior probability.[36] We selected the optimal model (ie, the optimal value of k) based on model fit indices and clinical interpretability. The selected indices were the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and entropy where lower values for Akaike and BIC as well as higher values for entropy indicate a better fitter model. We stopped fitting the model (ie, adding a new class) when AIC and BIC increased at the addition of a new class. The research team evaluated the interpretability and clinical coherence of the classes. For each variable category, the ratio of the class prevalence to the overall prevalence was colour coded in a heat map graphic representation and the most important differences gave their label to the classes (see online supp. table S4). To assess the relationship between class membership and the incidence of type 2 diabetes, we conducted logistic regressions analyses in a three-step process: first without adjustment variables (model 1), then adjusted for cardiometabolic risk factors (model 2), and finally adjusted for variables included in model 2 and sex (model 3).

We also conducted univariate and multivariate (non-adjusted and adjusted) logistic regression analyses of incident type 2 diabetes and sex, abdominal obesity and several socioeconomic variables to explore the magnitude of these associations compared with the relationship between class membership and incident type 2 diabetes (online supplemental table S3). As the highest rate of missing value is 2% (for physical activity) and no information gain can be expected from imputation with missing data rates below 5%,[39] list wise deletion was applied. We set statistical significance at p value <0.05 and conducted statistical analyses with STATA and R softwares.[40 41]

RESULTS

Baseline characteristics

From the 6733 participants who participated to the CoLaus|PsyCoLaus study at baseline, 3409 were included (50.62%). We excluded 18 (0.26%) participants with missing data for type 2 diabetes or type 1 diabetes at baseline, 119 (1.77%) participants with type 2 diabetes at baseline and 3187 (47.33%) participants with missing data for type 2 diabetes at third follow-up (due to loss to follow-up) (figure 2). Compared with included participants, participants excluded from analyses were older, more frequently men and social help recipients, and had less commonly any professional activity or a high or middle education level (online supplemental table S1).

In the final sample, 1893 participants were women (55.53%), and the mean age was 50.30 years (SD 9.75). Concerning gender-related factors, women were more frequently living alone with or without children, had more frequently a middle or low education level, received more social assistance and worked more often part time or not at all than men. Women had mostly middle qualified job, in standing position. They drank less alcohol, smoked less often, were less physically inactive and took more antidepressant drug treatment as their male counterparts. Regarding cardiometabolic risk factors, women had less frequently cardiovascular disease, high BP, dyslipidaemia, high-LDL or hypertriglyceridemia, and

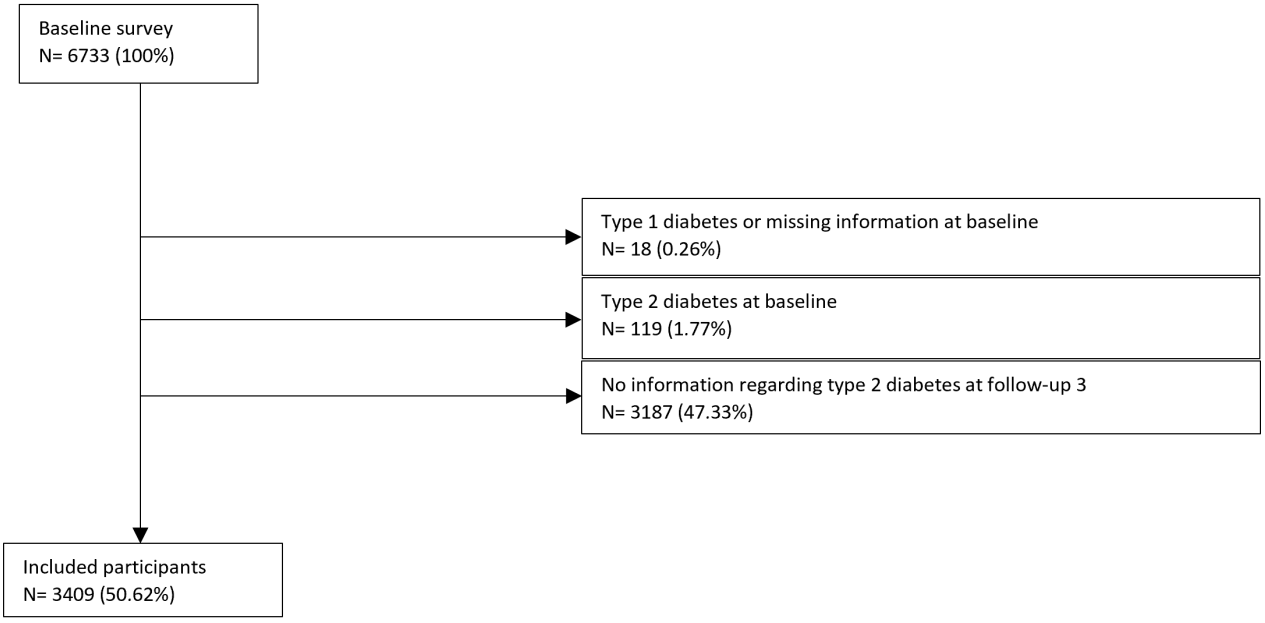

Figure 2 Study flowchart.

they had a lower BMI than men did. However, they had more frequently low-HDL levels and abdominal obesity (table 1).

Type 2 diabetes cumulative incidence and relative risks

Overall, 255 (7.48%) participants developed type 2 diabetes over a median follow-up time of 14.53 years (IQR 14.40–14.77 years). The sex-specific incidence was 10.42% in men and 5.12% in women, p<0.001, and the relative risk was reduced by two-third for women compared with men (OR 0.30, 95% CI 0.19 to 0.49, p<0.001). Living in couple also had a protective effect (OR 0.67, 95% CI 0.49 to 0.91, p=0.012), whereas abdominal obesity (OR 2.48, 95% CI 1.70 to 3.63, p<0.001) or lower educational level (OR 1.86, 95% CI 1.17 to 2.96, p=0.009) increased the probability of developing type 2 diabetes (online supplemental table S2).

Latent class modelling

A seven-class model was identified as optimal according to statistical indices (AIC 58989.9, BIC 59879.4, entropy 0.83) (online supplemental table S3). Descriptive characteristics of the latent classes are available in table 2. For 1805 (52.95%) participants, the probability of belonging to the class they were assigned to was >0.85, while for 332 (9.74%) participants, this probability was <0.55, indicating more ambiguous membership. The median posterior probability ranged from 0.71 (IQR 0.58–0.82) in class 3 to 0.99 (IQR 0.92–1.00) in class 5 (data not shown). These classes were considered as clinically relevant by the authors. The ratio (r) of the prevalence of each variable category within each class to the overall prevalence is available in online supplemental table S4 (ie, higher r meaning a higher prevalence in the class than in the overall sample). According to the smallest and highest r (which identifies variables whose distribution is the most different from the whole sample), classes were labelled as follows to represent their most specific characteristics: class 1 as *non-White physically inactive men and women*, class 2 as *highly qualified men, former or current smokers*, class 3 as *young, fit, educated men*, class 4 as *working women living alone*, class 5 as *low qualified working men with overweight*, class 6 as *women with obesity, low education and low qualified job or housewives* and class 7 as *low educated retired participants*. We observed a different constellation of socioeconomic and behavioural factors in every latent class generated and according to the predominant sex represented in the classes.

Regressions analyses of incident type 2 diabetes and latent classes

Class 3 (*young, fit, educated men*) was defined as the reference group for all regression analyses due to its favourable socioeconomic and behavioural profile compared with the other classes in relation to the risk of developing diabetes. In model 1 (ie, without adjustment), ORs were very high for the other classes (eg, OR 20.32, 95% CI 5.99 to 68.87, for class 1 *non-White physically inactive men and women*; OR 20.89, 95% CI 6.49 to 67.19, for class 5 *low qualified working men with overweight*) (figure 3). In model 2 (ie, after adjustment for cardiometabolic risk factors without integrating administrative sex), the magnitude of the ORs decreased by a twofold to threefold factor but remained statistically significant, except for class 4 *working women living alone* whose odds were no longer significantly different from reference group (figure 3). Model 3 (ie, adjusted as in model 2 plus for administrative sex) allows the interpretation of the ORs as associations of gender profiles with the probability of developing type 2 diabetes, independently of sex, age and other cardiometabolic risk factors. In this model, each

Table 1 Baseline characteristics of participants overall and according to sex.

	All participants (N=3409)	Women (N=1893)	Men (N=1516)	P value
Age (years)	50.30 (9.75)	51.19 (9.81)	49.20 (9.56)	<0.001
Age categories				0.003
35–54 years old	3954 (58.73)	2022 (57.05)	1932 (60.58)	
55–75 years old	2779 (41.27)	1522 (42.95)	1257 (39.42)	
Born in Switzerland	2162 (63.42)	1212 (64.03)	950 (62.66)	0.412
'White' as self-reported race	3122 (91.23)	1740 (91.70)	1382 (91.64)	0.254
Gender-related factors				
Current domestic situation				<0.001
Alone	791 (23.20)	532 (28.10)	259 (17.08)	
Monoparental family	274 (8.04)	227 (11.99)	47 (3.10)	
Couple without children	861 (25.26)	437 (23.09)	425 (27.97)	
Couple with children	1483 (43.50)	698 (36.82)	786 (51.85)	
Education				<0.001
High	791 (23.21)	357 (18.86)	434 (28.65)	
Middle	939 (27.55)	540 (28.53)	399 (26.34)	
Low	1678 (49.24)	996 (52.61)	682 (45.02)	
Receiving social assistance				<0.001
Yes	583 (17.10)	375 (19.81)	208 (13.72)	
No	2813 (82.52)	1512 (79.87)	1301 (85.82)	
Does not know	13 (0.38)	6 (0.32)	7 (0.46)	
Professional status				<0.001
Professional activity≥50%	2441 (71.60)	1166 (61.60)	1275 (84.10)	
Professional activity<50%	171 (5.02)	134 (7.08)	37 (2.44)	
Staying at home	797 (23.38)	593 (31.33)	204 (13.46)	
Current job type*				**<0.001**
High qualified work	505 (14.83)	138 (7.29)	367 (24.24)	
Middle qualified work	1599 (46.95)	977 (51.64)	622 (41.08)	
Low qualified work	598 (17.56)	251 (13.27)	347 (22.92)	
Not working	704 (20.67)	526 (27.80)	178 (11.76)	
Job-related physical intensity				<0.001
Sitting	1363 (40.09)	710 (37.63)	653 (43.13)	
Standing	1385 (40.72)	887 (47.01)	498 (32.89)	
Carry light load	447 (13.14)	235 (12.45)	212 (14.00)	
Carry heavy load	206 (6.06)	55 (2.91)	151 (9.97)	
Weekly alcohol unit consumption				<0.001
0	860 (25.23)	623 (32.91)	237 (15.63)	
1–13 units	2050 (60.13)	1159 (61.23)	891 (58.77)	
14–27 units	407 (11.94)	102 (5.39)	305 (20.12)	
≥ 28 units	92 (2.70)	9 (0.48)	83 (5.47)	
Smoking status				<0.001
Never	1457 (42.74)	880 (46.49)	578 (38.06)	
Former	1131 (33.18)	577 (30.48)	554 (36.54)	
Current	821 (24.08)	436 (23.03)	385 (25.40)	
Physical activity (min.2×20 minutes/week)	1914 (56.29)	1104 (59.71)	810 (54.29)	0.002
Antidepressant drug treatment	281 (8.24)	201 (10.62)	80 (5.28)	<0.001

Continued

Table 1 Continued

	All participants (N=3409)	Women (N=1893)	Men (N=1516)	P value
Cardiometabolic data				
Baseline cardiovascular disease	55 (1.61)	19 (1.00)	36 (2.37)	0.002
High blood pressure	942 (27.65)	454 (24.00)	488 (32.21)	<0.001
Dyslipidaemia	2022 (59.31)	988 (52.19)	1034 (68.21)	<0.001
Family history for diabetes				0.507
Yes	621 (18.22)	356 (18.81)	265 (17.48)	
Does not know	278 (8.15)	158 (8.35)	120 (7.92)	
BMI (kg/m^2)	24.62 (22.16–27.36)	23.53 (21.30–26.71)	25.56 (23.62–27.83)	<0.001
Weight categories				<0.001
Normal weight	1848 (54.21)	1190 (62.86)	658 (43.40)	
Overweight	1201 (35.23)	500 (26.41)	701 (46.24)	
Obese	360 (10.56)	203 (10.72)	157 (10.36)	
Abdominal obesity	796 (23.36)	524 (27.70)	272 (17.94)	<0.001
Polycystic ovary syndrome				
Yes	13 (0.69)	13 (0.69)		NA
Does not know	6 (0.32)	6 (0.32)		NA
Gestational diabetes history				
Yes	19 (1.00)	19 (1.00)		NA
Does not know	8 (0.42)	8 (0.42)		NA
Never pregnant	381 (20.13)	381 (20.13)		NA
Menopaused				
Yes	887 (46.86)	887 (46.86)		NA
Does not know	17 (0.90)	17 (0.90)		NA

*Current job type: 'high qualification' for entrepreneur, liberal profession and senior management; 'middle qualification' for independent worker, middle management and qualified worker; 'low qualification' for employed worker, farmer, unqualified worker, manoeuvre; 'not working'; Job-related physical activity: sitting (eg, watch maker, telephone operator), standing (eg, saleswoman/man, hairdresser), carrying light load (eg, postwoman/man, waitress/waiter, building painter), carrying heavy load (eg, mover, labourer on construction site).

class had significant higher OR than class 3 *young, fit, educated men*. More precisely and compared with model 2, the ORs for class 2 *highly qualified men, former or current smokers* and class 5 *low qualified working men with overweight* (both classes including almost only men) were attenuated while ORs increased for all other classes (containing more women than men) (figure 3).

DISCUSSION

This study uniquely assessed the role of gender as an intersectional sociological concept on the incidence of type 2 diabetes through an exploratory methodology using LCA. Overall, the cumulative incidence of type 2 diabetes in our sample was 7.48% with a 70% increased likelihood of developing diabetes for men compared with women. However, we observed a gendered distribution of the intersectional social position and a deleterious effect of the feminine gender profile.

The higher incidence of type 2 diabetes among men in our study was consistent with known European data on prevalence and burden of disease across the same period[1 11 12] with a high relative risk difference. As observed in other studies,[17 42] women without type 2 diabetes had a healthier cardiometabolic profile at baseline but a more unfavourable socioeconomic profile than men without type 2 diabetes. Unsurprisingly in view of these cohesive results, the seven latent classes identified correspond to social groups encountered in our regional clinical practice, with a distribution of socioeconomic risk factors reflecting their gendered distribution. As an example, the class with more former or current smokers (representing the conformity to gender norms on the individual level of the gender dimension) and high work qualification (representing gender roles on the interactional level of the gender dimension) included more men. Men were also more numerous in the class with a higher proportion of highly educated (representing institutionalised gender), physically active people of normal weight (representing conformity to gender norms on the individual level of the gender dimension). On the contrary, women outnumbered men in the class with a majority living alone while working mainly part time

Table 2 Prevalence of each categorical variable within each of the seven classes generated by latent class analysis

	Class 1 *'Non-White physically inactive men and women'* (N=170)	Class 2 *'Highly qualified men, former or current smokers'* (N=557)	Class 3 *'Young, fit, educated men'* (N=413)	Class 4 *'Working women living alone'* (N=914)	Class 5 *'Low qualified working men with overweight'* (N=445)	Class 6 *'Women with obesity, low education, and low qualified job or housewives'* (N=329)	Class 7 *'Low educated retired participants'* (N=581)
Woman as administrative sex	0.62	0.00	0.41	0.93	0.09	1.00	0.68
35–44 years old	0.50	0.29	0.75	0.28	0.52	0.36	0.05
45–54 years old	0.38	0.41	0.25	0.43	0.31	0.39	0.09
55–64 years old	0.11	0.29	0.00	0.27	0.16	0.25	0.43
65–75 years old	0.02	0.01	0.00	0.01	0.00	0.00	0.43
'White' as self-reported race	0.00	0.95	0.98	1.00	0.92	0.95	0.99
Living in couple	0.66	0.90	0.76	0.46	0.78	0.82	0.65
Not receiving social help	0.76	0.98	0.97	0.89	0.82	0.90	0.46
High education level	0.38	0.39	0.62	0.19	0.01	0.08	0.09
Middle education level	0.41	0.37	0.24	0.35	0.12	0.12	0.27
Low education level	0.21	0.24	0.14	0.47	0.87	0.79	0.65
Professional activity≥50%	0.75	0.99	0.97	0.88	0.94	0.42	0.00
Professional activity<50%	0.00	0.01	0.01	0.11	0.03	0.09	0.02
Staying at home	0.25	0.00	0.02	0.00	0.03	0.49	0.98
Highly or middle qualified job	0.76	1.00	1.00	1.00	0.16	0.00	0.04
Sitting at work	0.35	0.64	0.67	0.47	0.10	0.13	0.27
Standing at work or carrying light loads	0.60	0.36	0.33	0.50	0.53	0.87	0.72
Carrying heavy loads	0.05	0.00	0.00	0.02	0.37	0.00	0.01
Weekly alcohol consumption at low risk	0.95	0.94	1.00	0.92	0.94	0.97	0.92
Former or current smoker	0.45	0.70	0.31	0.66	0.67	0.41	0.55
Physically active	0.08	0.56	0.78	0.63	0.36	0.47	0.69
No antidepressant drug treatment	1.00	0.95	1.00	0.87	0.96	0.90	0.87
Weight normal	0.55	0.24	0.97	0.66	0.34	0.58	0.48
Overweight	0.31	0.65	0.02	0.25	0.54	0.24	0.39
Obese	0.14	0.11	0.00	0.09	0.12	0.18	0.13

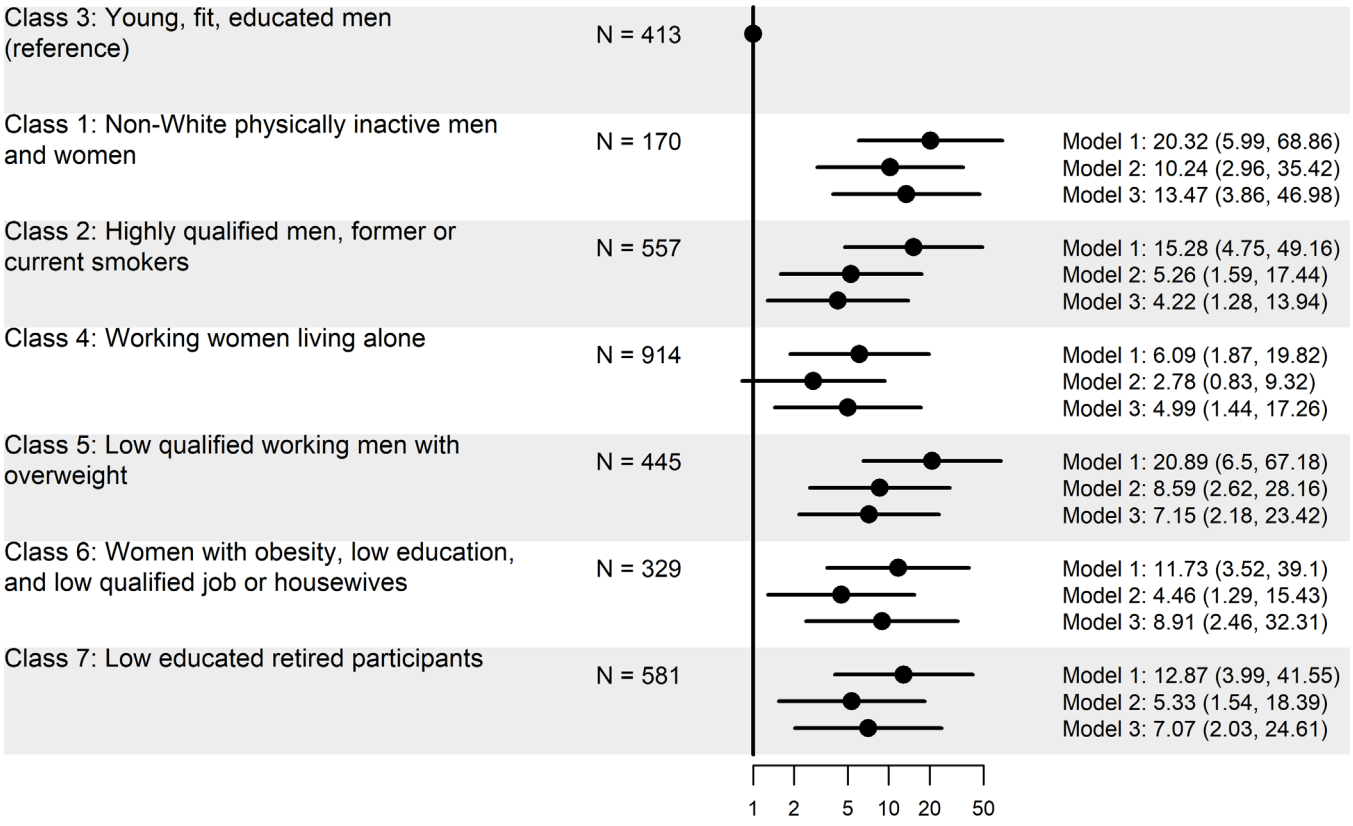

Figure 3 Non-adjusted and adjusted OR with 95% CIs for incident type 2 diabetes by latent class. Model 1: non-adjusted ORs; model 2: ORs adjusted for cardiometabolic risk factors; model 3: ORs adjusted for cardiometabolic risk factors and administrative sex.

and in the class with a predominance of individuals with low education, low qualified jobs or housewives and with obesity (representing gender roles and gender relations on the interactional level of gender).

However, due to the independence of the variables within a class, the same gender profile was found in any member of one class, regardless of their administrative sex or age category. This allowed us to compare gender profiles across classes: each class had significant higher OR than the class of *young, fit, educated men* with the ORs for classes containing almost only men (ie, class 2 *Highly qualified men, former or current smokers* and class 5 *low qualified working men with overweight*) decreasing when adjusting for sex in addition to other cardiometabolic risk factors, including age. The opposite was true for women-dominated classes, reflecting the unfavourable biological profile of men. However, classes mostly feminine (class 4: OR=4.99, 95% CI 1.44 to 17.26, class 6: OR 8.91, 95% CI 2.46 to 32.31) showed globally higher ORs than male dominated classes (class 3: OR 1 (reference), class 2: OR 4.22 95% CI 1.28 to 13.94, class 5: OR 7.15 2.18 to 23.42). Compared with socially advantaged groups, people with disadvantaged intersectional positions have a higher overall risk of chronic diseases. Several hypotheses support this association: chronic stress,[43] the concept of embodiment[44] (*how gender oppression might 'get under the skin' to affect the health of women and gender minorities*[24]), and multidirectional links between several factors including depression and obesity.[42] The latter is also more prevalent in lower socioeconomic environments and a strong independent risk factor for type 2 diabetes with an analogy to countries with low sociodemographic index.[1] These elements were reflected in our results: classes with a higher risk of developing type 2 diabetes than the reference represented socially disadvantaged groups. These dynamics explained the unfavourable gender profile of the predominantly feminine classes: for instance, '*working women living alone*' represented a low socioeconomic position group in Switzerland as women are more exposed (and increasingly so) to 'non-traditional' risk factors (eg, stress at work, problems arranging work with family duties, major depression, etc).[17]

Consequently, we conclude that LCA can be an effective method for integrating gender into epidemiological data with an intersectional perspective.[45]

Strengths and limitations

Strengths of this study are precise data on socioeconomic status and health-related behaviours collected longitudinally. It allowed an intersectional approach that went beyond traditional sex-stratified analyses or gender scores. Furthermore, LCA revealed higher risk groups

(ie, high ORs) than regression analyses incorporating administrative sex, socioeconomic and cardiometabolic risk factors and health behaviours separately. This study has several limitations. First, its single-centre design with important loss to follow-up and limited sample size prevents causal and generalisable conclusions, as the local context is inextricably linked to type 2 diabetes epidemiology. Survival analyses could not be carried out with a single follow-up, although they could have refined the analyses. However, important variables such as education, living situation and work qualification show little change in older adults and fundamental changes in results are unlikely. Second, the primary study was developed more than 20 years ago, and decisions—such as the exclusion of non-French speakers—are debatable. This study has a potential representativeness bias with more privileged participants included in the original study as shown by the characteristics of the patients excluded from this secondary analysis. Third, the absence of HbA1c measurement at baseline and systematic oral glucose tolerance test (oGTT) reflecting postprandial insulin resistance may underestimate the incidence of type 2 diabetes, particularly in women regarding oGTT.[2] Finally, the lack of standardised gender measurement tool limits comparison with existing studies.

Perspectives

Better theoretical framework and operationalisation guidelines are required to improve gender-sensitive analyses in bio-medical research. The exploration of this operationalisation is essential to the integration of gender as a variable, leading to improved quality and equity of care.[24] A discussion on the epistemological framework in which this research is embedded is also necessary since *our beliefs about gender affects what kinds of knowledge scientists produce about sex in the first place.*[46] Our study also highlights uncertainty in the optimal segmentation methodology for populations with type 2 diabetes.[47] Examining gender as a segmentation method can help to recognise the interconnectedness of demographics, socioeconomic factors, and health behaviours, especially in lifestyle-related chronic diseases.

Further exploration is needed for applying this approach in prevention and clinical practice, especially in underprivileged populations. The unexpected OR magnitudes underscore the necessity of integrating an intersectional approach in diverse populations/databases for comparison.

Conclusions

LCA allow the operationalisation of an intersectional approach of gender as an epidemiological risk factor for type 2 diabetes incidence beyond traditional sex-stratified analyses. Cumulative intersectional effects across behavioural and socioeconomic profiles emphasise on the deleterious effect of a feminine gender profile. Considering multifactorial aspects of gender in the evaluation of epidemiological risk factors seem to be a promising approach to better understand complex diseases such as type 2 diabetes. Prevention strategies should also account for gender to better approach unprivileged groups of the population.

Contributors JV is the principal investigator of the CoLaus|PsyCoLaus study. JMB designed the analyses with input from all other authors. JMB and MA conducted the statistical analyses. JMB drafted the first version and successive drafts of the present manuscript. JV, JS, MA, AML and CC contributed to the results interpretation, refinement of the methods and critically revised the manuscript. All authors approved the final manuscript to be published. CC and JV had complete access to all data and are guarantors for the content of this report.

Funding The CoLaus|PsyCoLaus study is supported by research grants from GlaxoSmithKline, the Faculty of Biology and Medicine of Lausanne, and the Swiss National Science Foundation (grant numbers 33CSCO-122661, 33CS30-139468, 33CS30-148401, 32003B_173092 and 33CS30_177535/1). The funding sources had no involvement in the study design, data collection, analysis and interpretation, writing of the report, or decision to submit the article for publication.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Local Ethics Committee: Commission cantonale d'éthique de la recherche sur l'être humain (CER-VD) project number: PB_2018-00038, reference 239/09. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer-reviewed.

Data availability statement Data are available upon reasonable request. The datasets generated during and/or analysed during the current study are not publicly available. Information related to data access can be made available to interested researchers at https://www.colaus-psycolaus.ch/professionals/how-to-collaborate/.

Author note CC and JS are joint last authors.

ORCID iDs
Jeanne Marie Barbier http://orcid.org/0000-0001-8259-1761
Michael Amiguet http://orcid.org/0000-0003-3925-6663
Julien Vaucher http://orcid.org/0000-0002-3230-3693

REFERENCES

1 Saeedi P, Petersohn I, Salpea P, *et al*. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. *Diabetes Res Clin Pract* 2019;157:107843.
2 Kautzky-Willer A, Harreiter J, Pacini G. Sex and Gender Differences in Risk, Pathophysiology and Complications of Type 2 Diabetes Mellitus. *Endocr Rev* 2016;37:278–316.
3 Huebschmann AG, Huxley RR, Kohrt WM, *et al*. Sex differences in the burden of type 2 diabetes and cardiovascular risk across the life course. *Diabetologia* 2019;62:1761–72.
4 Suwannaphant K, Laohasiriwong W, Puttanapong N, *et al*. Association between Socioeconomic Status and Diabetes Mellitus:

The National Socioeconomics Survey, 2010 and 2012. *J Clin Diagn Res* 2017;11:LC18–22.
5 Stringhini S, Zaninotto P, Kumari M, *et al*. Lifecourse socioeconomic status and type 2 diabetes: the role of chronic inflammation in the English Longitudinal Study of Ageing. *Sci Rep* 2016;6:24780.
6 Cooper AJ, Gupta SR, Moustafa AF, *et al*. Sex/Gender Differences in Obesity Prevalence, Comorbidities, and Treatment. *Curr Obes Rep* 2021;10:458–66.
7 Clair C, Augsburger A, Birrer P, *et al*. Assessing the efficacy and impact of a personalised smoking cessation intervention among type 2 diabetic smokers: study protocol for an open-label randomised controlled trial (DISCGO-RCT). *BMJ Open* 2020;10:e040117.
8 Kraege V, Vollenweider P, Waeber G, *et al*. Development and multi-cohort validation of a clinical score for predicting type 2 diabetes mellitus. *Plos One* 2019;14:e0218933.
9 Knol MJ, Twisk JWR, Beekman ATF, *et al*. Depression as A risk factor for the onset of type 2 diabetes mellitus. A meta-analysis. *Diabetologia* 2006;49:837–45.
10 Puka K, Buckley C, Mulia N, *et al*. Educational Attainment and Lifestyle Risk Factors Associated With All-Cause Mortality in the US. *JAMA Health Forum* 2022;3:e220401.
11 de Mestral C, Stringhini S, Guessous I, *et al*. Thirteen-year trends in the prevalence of diabetes according to socioeconomic condition and cardiovascular risk factors in a Swiss population. *BMJ Open Diabetes Res Care* 2020;8:e001273.
12 Lin X, Xu Y, Pan X, *et al*. Global, regional, and national burden and trend of diabetes in 195 countries and territories: an analysis from 1990 to 2025. *Sci Rep* 2020;10.
13 Kaiser A, Vollenweider P, Waeber G, *et al*. Prevalence, awareness and treatment of type 2 diabetes mellitus in Switzerland: the CoLaus study. *Diabet Med* 2012;29:190–7.
14 Tinajero MG, Malik VS. An Update on the Epidemiology of Type 2 Diabetes: A Global Perspective. *Endocrinol Metab Clin North Am* 2021;50:337–55.
15 Firmann M, Mayor V, Vidal PM, *et al*. The CoLaus study: a population-based study to investigate the epidemiology and genetic determinants of cardiovascular risk factors and metabolic syndrome. *BMC Cardiovasc Disord* 2008;8:6.
16 Stringhini S, Spencer B, Marques-Vidal P, *et al*. Age and gender differences in the social patterning of cardiovascular risk factors in Switzerland: the CoLaus study. *PLOS ONE* 2012;7:e49443.
17 Hänsel M, Steigmiller K, Luft AR, *et al*. Neurovascular disease in Switzerland: 10-year trends show non-traditional risk factors on the rise and higher exposure in women. *Eur J Neurol* 2022;29:2851–60.
18 Marques-Vidal P, Vollenweider P, Waeber G. Alcohol consumption and incidence of type 2 diabetes. Results from the CoLaus study. *Nutr Metab Cardiovasc Dis* 2015;25:75–84.
19 Cifkova R, Pitha J, Krajcoviechova A, *et al*. Is the impact of conventional risk factors the same in men and women? Plea for a more gender-specific approach. *Int J Cardiol* 2019;286:214–9.
20 Ding EL, Song Y, Malik VS, *et al*. Sex differences of endogenous sex hormones and risk of type 2 diabetes: a systematic review and meta-analysis. *JAMA* 2006;295:1288–99.
21 Wannamethee SG, Papacosta O, Lawlor DA, *et al*. Do women exhibit greater differences in established and novel risk factors between diabetes and non-diabetes than men? The British Regional Heart Study and British Women's Heart Health Study. *Diabetologia* 2012;55:80–7.
22 Peters SAE, Huxley RR, Sattar N, *et al*. Sex Differences in the Excess Risk of Cardiovascular Diseases Associated with Type 2 Diabetes: Potential Explanations and Clinical Implications. *Curr Cardiovasc Risk Rep* 2015;9:36.
23 Kelly C, Dansereau L, Sebring J, *et al*. Intersectionality, health equity, and EDI: What's the difference for health researchers? *Int J Equity Health* 2022;21:182.
24 Heise L, Greene ME, Opper N, *et al*. Gender inequality and restrictive gender norms: framing the challenges to health. *Lancet* 2019;393:2440–54.
25 Krieger N. Genders, sexes, and health: what are the connections--and why does it matter? *Int J Epidemiol* 2003;32:652–7.
26 Tannenbaum C, Ellis RP, Eyssel F, *et al*. Sex and gender analysis improves science and engineering. *Nature* 2019;575:137–46.
27 Schiebinger L, Klinge I. Gendered Innovation in Health and Medicine. *Adv Exp Med Biol* 2018;1065:643–54.
28 Raparelli V, Norris CM, Bender U, *et al*. Identification and inclusion of gender factors in retrospective cohort studies: the GOING-FWD framework. *BMJ Glob Health* 2021;6:e005413.
29 Colineaux H, Soulier A, Lepage B, *et al*. Considering sex and gender in Epidemiology: a challenge beyond terminology. From conceptual analysis to methodological strategies. *Biol Sex Differ* 2022;13:23.
30 Pelletier R, Khan NA, Cox J, *et al*. Sex Versus Gender-Related Characteristics: Which Predicts Outcome After Acute Coronary Syndrome in the Young? *J Am Coll Cardiol* 2016;67:127–35.
31 Alipour P, Azizi Z, Raparelli V, *et al*. Role of sex and gender-related variables in development of metabolic syndrome: A prospective cohort study. *Eur J Intern Med* 2023:S0953-6205(23)00352-7.
32 Preisig M, Waeber G, Vollenweider P, *et al*. The PsyCoLaus study: methodology and characteristics of the sample of a population-based survey on psychiatric disorders and their association with genetic and cardiovascular risk factors. *BMC Psychiatry* 2009;9:9.
33 Health and Gender Unit. The Gender Toolbox: Recommendations for Health Researchers. Lausanne, Unisanté - Center for primary care and public health. 2021. Available: https://www.unisante.ch/sites/default/files/inline-files/The%20Gender%20Toolbox_2022-01-19_publi%C3%A9e%20janv%202023_0.pdf
34 Organization WH. Waist circumference and waist-hip ratio: report of a WHO expert consultation, Geneva, 8-11 December 2008. 2011.
35 Sinha P, Calfee CS, Delucchi KL. Practitioner's Guide to Latent Class Analysis: Methodological Considerations and Common Pitfalls. *Crit Care Med* 2021;49:e63–79.
36 Weller BE, Bowen NK, Faubert SJ. Latent class analysis: a guide to best practice. *J Black Psychol* 2020;46:287–311.
37 Borodulin K, Zimmer C, Sippola R, *et al*. Health Behaviours as Mediating Pathways between Socioeconomic Position and Body Mass Index. *IntJ Behav Med* 2012;19:14–22.
38 Seng JJB, Kwan YH, Lee VSY, *et al*. Differential Health Care Use, Diabetes-Related Complications, and Mortality Among Five Unique Classes of Patients With Type 2 Diabetes in Singapore: A Latent Class Analysis of 71,125 Patients. *Diabetes Care* 2020;43:1048–56.
39 Lee KJ, Roberts G, Doyle LW, *et al*. Multiple imputation for missing data in a longitudinal cohort study: a tutorial based on a detailed case study involving imputation of missing outcome data. *Int J Soc Res Methodol* 2016;19:575–91.
40 StataCorp. *Stata Statistical Software: Release 17*. College Station, TX: StataCorp LLC, 2021.
41 R Foundation for Statistical Computing. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing, 2022. Available: https://www.R-project.org
42 Stringhini S, Tabak AG, Akbaraly TN, *et al*. Contribution of modifiable risk factors to social inequalities in type 2 diabetes: prospective Whitehall II cohort study. *BMJ* 2012;345:e5452.
43 Petrovic D, Pivin E, Ponte B, *et al*. Sociodemographic, behavioral and genetic determinants of allostatic load in a Swiss population-based study. *Psychoneuroendocrinology* 2016;67:76–85.
44 Fausto-Sterling A. The Bare Bones of Sex: Part 1—Sex and Gender. *Signs: J Women Culture Soc* 2005;30:1491–527.
45 Bauer GR, Churchill SM, Mahendran M, *et al*. Intersectionality in quantitative research: A systematic review of its emergence and applications of theory and methods. *SSM Popul Health* 2021;14:100798.
46 Kuhlmann E, Babitsch B. Bodies, health, gender—bridging feminist theories and women's health. *Women's Studies International Forum* 2002;25:433–42.
47 Seng JJB, Monteiro AY, Kwan YH, *et al*. Population segmentation of type 2 diabetes mellitus patients and its clinical applications - a scoping review. *BMC Med Res Methodol* 2021;21:49.