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Original Article

Cohort study on incidence of new-onset type 2 diabetes in patients after bariatric surgery and matched controls

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Abstract

Background: Metabolic bariatric surgery the reduces risk of new-onset type 2 diabetes in individuals with obesity, but it is unclear whether the benefit varies by sex, age, or socioeconomic status. The aim was to assess the risk of new-onset type 2 diabetes after metabolic bariatric surgery in these subgroups.

Methods: The Finnish Public Sector study, a follow-up study with matched controls nested in a large employee cohort, included patients without type 2 diabetes and with a diagnosis of obesity or self-reported BMI of at least 35 kg/m^2. For each patient who had laparoscopic metabolic bariatric surgery (2008–2016), two propensity-score matched controls were selected. New-onset type 2 diabetes was ascertained from linked records from national health registries.

Results: The study included a total of 917 patients and 1811 matched controls with obesity. New-onset type 2 diabetes was diagnosed in 15 of the patients who had metabolic bariatric surgery (4.1 per 1000 person-years) and 164 controls (20.2 per 1000 person-years). The corresponding rate ratio (RR) was 0.20 (95% c.i. 0.12 to 0.35) and the rate difference (RD) was −16.1 (−19.8 to −12.3) per 1000 person-years. The risk reduction was more marked in individuals of low socioeconomic status (RR 0.10 (0.04 to 0.26) and RD −20.6 (−25.6 to −15.5) per 1000 person-years) than in those with higher socioeconomic status (RR 0.35 (0.18 to 0.66) and RD −11.5 (−16.9 to −6.0) per 1000 person-years) ($P_{interaction} = 0.017$). No differences were observed between sexes or age groups.

Conclusion: Metabolic bariatric surgery was associated with a reduced risk of new-onset type 2 diabetes in men and women and in all age groups. The greatest benefit was observed in individuals of low socioeconomic status.

Lay summary

Metabolic bariatric surgery reduces the risk of new-onset type 2 diabetes in individuals with obesity or severe obesity. The risk of new-onset type 2 diabetes after metabolic bariatric surgery varies between socioeconomic status subgroups. In this prospective study, new-onset type 2 diabetes occurred in 1.6% of 917 patients who underwent metabolic bariatric surgery and 9.1% of 1811 propensity score-matched controls. Risk reduction was more marked in individuals of low socioeconomic status. There were no differences between sex or age groups. The reduced risk of new-onset type 2 diabetes after metabolic bariatric surgery emphasizes the need to increase access to treatment in patients with severe obesity. As the preventive effect was most pronounced in individuals of low socioeconomic status associated with both greater burden of disease and worse access to healthcare, the findings need to be taken into account in health policies to reduce health inequalities.

Introduction

The age-standardized burden of chronic diseases has declined worldwide over the past 30 years, but the burden of metabolic disorders has not decreased[1]. The prevalence of obesity has nearly tripled since 1975 and, by year 2030, it is estimated that 20% of world's population will have obesity (body BMI 30 kg/m^2 or higher)[2–4]. Simultaneously, the global burden of diabetes has nearly doubled since 1990[1]. Obesity is one of the leading causes of preventable premature death and the leading cause of type 2 diabetes (T2DM), a major risk factor for cardiovascular diseases[5]. Despite the fact that hyperglycaemia and obesity now

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rank as the third and fifth leading risk factors for the global burden of disease[5], prevention and access to effective medical and surgical treatments for metabolic syndrome are insufficient[6].

Metabolic bariatric surgery (MBS) has been established as the most effective treatment for severe obesity, often resulting in sustainable weight loss and remission of obesity-related co-morbidities[7–9]. Compared with non-surgical and medical treatments, bariatric surgery is superior in achieving glycaemic control and remission of T2DM in people with obesity[10,11]. Bariatric surgery is also associated with a reduced risk of cardiovascular diseases, cardiovascular mortality, and all-cause mortality[2,12–14]. International guidelines for MBS initially dating from 1991[15] were updated in October 2022[16] to expand this effective and safe surgical treatment to patients with a BMI of at least 35 kg/m^2 regardless of metabolic disorders, lowering the threshold from the previous BMI value of 40 kg/m^2. In 2018, a consensus statement[17] by the American Diabetes Association and the European Association for the Study of Diabetes recommended metabolic surgery for patients with a BMI of between 30 and 34.9 kg/m^2 with poorly controlled T2DM despite optimal medical therapy.

Although bariatric surgery is highly effective in treating patients with obesity and T2DM, its effect on preventing new-onset T2DM in patients with obesity and no T2DM remains unclear. The Swedish Obesity Study landmark trial[18] suggested that bariatric surgery is significantly more efficient in the prevention of T2DM in patients with obesity than standard conservative weight-management treatment. Other studies assessing the preventive effect of MBS on new-onset T2DM are observational and mostly based on clinical cohorts. In seven follow-up studies[19–25] of population-based cohorts with highly variable results, the relative risk for new-onset T2DM after bariatric surgery compared with controls ranged from 0.14 to 0.77. However, these studies were limited by insufficient control for major confounding factors, most importantly socioeconomic status (SES)[2]. SES may modify the effects of bariatric surgery for at least two reasons. First, the likelihood of receiving bariatric surgery may be affected by SES, the access being worse among those with socioeconomic disadvantage[26]. Second, some socioeconomic pattern factors, such as non-adherence to postoperative medical procedures, may be associated with weight loss outcomes after bariatric surgery[27]. There are no studies assessing either the association between bariatric surgery and risk of new-onset T2DM by SES or in comparison to individuals with different classes of obesity[2,16,28].

In this cohort study, the risk of new-onset T2DM was compared between patients who underwent bariatric surgery and propensity score-matched controls, including subgroup analyses by sociodemographic characteristics and obesity class.

Methods

Study population

The study population of patients who underwent bariatric surgery and matched controls was obtained from the Finnish Public Sector (FPS) study, an ongoing dynamic cohort study with repeated questionnaire follow-up every 2–4 years and linkage to electronic health records. The FPS was established in 1997–1998 and comprises employees with a job contract for a minimum of 6 months in the municipal services of 6 largest cities and 5 smaller towns, and 21 public hospitals in Finland[29]. A total of 477 509 individuals participating in FPS had data on socioeconomic factors and were successfully linked to national health records until 31 December 2016. The ethics committee of the Hospital District of Helsinki and Uusimaa approved the FPS study (registration number HUS/1210/2016).

Patients who had bariatric surgery and eligible comparison group

Individuals who underwent primary laparoscopic Roux-en-Y gastric bypass (LRYGB) or laparoscopic sleeve gastrectomy (LSG) between 2008 and 2016 were included. All study patients were recorded in the National Care Register for Health Care, maintained by the National Institute for Health and Welfare. The validity for bariatric surgery codes is high in this registry. It is mandatory practice for both public and private hospitals to record inpatient data including diagnoses, procedure codes, and dates of discharge of every patient in the National Care Register. The codes used to identify patients undergoing MBS are unique to the primary MBS and are used similarly in all hospitals performing MBS in Finland. A pool of individuals with obesity and no history of bariatric surgery were selected as controls. First, all cohort members were identified who had been hospitalized with the diagnoses for obesity (ICD-10 code E66) for reasons other than bariatric surgery, and those with a BMI of at least 35 kg/m^2 based on self-reported body height and weight from one or more of the three surveys conducted between 2008 and 2014. Excluded were all participants from the bariatric and eligible comparison groups with prevalent diabetes (ICD-10 diagnoses E10–E14) at baseline.

Ascertainment of new-onset type 2 diabetes

The participants were linked to nationwide health and population registries using the unique personal identification numbers in Finland. T2DM was identified with ICD-10 code E11 in the hospital discharge registry and with the eligibility for special reimbursement in the Drug Prescription Register, as in the authors' previous studies. The register maintained by the Social Insurance Institution listed all individuals fulfilling the diagnostic criteria for T2DM with physician-documented evidence (fasting plasma glucose over 7.0 mmol/l, or a non-fasting plasma glucose above 11.1 mmol/l and symptoms of diabetes)[29–31]. Follow-up started at the date of bariatric surgery for cases and the date of the recording of obesity (from hospital records or survey response) for controls and lasted until 31 December 2016.

Co-variables

Baseline co-variables were obtained via record linkage by the identification number of the participants to national registries. These included sociodemographic factors, area characteristics, and chronic medical conditions. Age, sex, and occupational titles were derived from employers' records and educational attainment from Statistics Finland. SES was defined by occupational position, educational attainment, and level of neighbourhood disadvantage; detailed definitions have been published previously[29]. Based on records of granted work disability pensions and statutory pensions obtained from the Finnish Centre of Pensions, the participants were classified as not retired, retired owing to work disability, or retired based on age. Information on chronic medical conditions was obtained from national health registries. Healthcare provider-related differences were indicated by place of residence (city, town or rural) and hospital district (5 districts). Details of measurement of the co-variables are presented in the *supplementary material*, and the distribution of co-variables in the bariatric group and controls in Table S1.

Propensity score matching

For all patients in the bariatric surgery and non-surgery comparison groups, a logistic regression model was constructed with bariatric surgery as the outcome, and sex, age group, SES, retirement, diagnosed medical conditions, place of residence, and hospital district defined before the index date as co-variables. The model also included the interactions of the co-variables with sex, age group, and SES. For sensitivity analyses, four alternative control groups were defined: clinical controls only; non-clinical survey controls with BMI 30–34.9 kg/m^2; those with BMI 35–39.9 kg/m^2; and those with BMI 40 kg/m^2 or higher.

Statistical analysis

Each bariatric surgery case was matched 1 : 2 with non-surgery controls with the same propensity score. The balance achieved by matching was studied using the χ^2 test for each baseline variable to determine any imbalances.

To examine the risk of new-onset T2DM among bariatric surgery cases and their matched controls, follow-up started at the index date: hospitalization for bariatric surgery, and hospitalization with an ICD-10 code of obesity but no bariatric surgery, or the date of survey response with a BMI 35 kg/m^2 or more for those not admitted to hospital with an ICD-10 code of obesity. Follow-up continued until disease onset, death, or end of follow-up (31 December 2016), whichever came first. To depict the association between bariatric surgery and new-onset T2DM across the follow-up, cumulative hazard curves for the bariatric surgery cases and their matched controls were prepared. Poisson regression models were used to estimate the rate of new-onset T2DM per 1000 person-years with 95% confidence intervals in the bariatric surgery and control groups, and the corresponding rate ratio (RR) and rate difference (RD) with 95% confidence intervals. To examine whether the associations varied between demographic subgroups, contrasts in the Poisson regression models were used. These included the demographic factor, the treatment group, and their interaction term to estimate the rates, RRs, and RDs for men and women, for those aged less than 50 years and 50 years or more, and for those of low SES or not.

In sensitivity analyses, first, cumulative hazard curves were constructed, and the rates, RRs, and RDs estimated as in the main analyses comparing the risk of patients undergoing bariatric surgery with four alternative propensity score-matched control groups (clinical controls only and non-clinical survey controls with BMI 40 or more, 35–39.9, or 30–34.9 kg/m^2), matched 1 : 1. Second, the main analyses were replicated using a minimum 1-year lag between the index date and the date of the occurrence of T2DM to take into account the possibility that non-diagnosed prevalent T2DM would be more likely among the non-surgery controls than the bariatric surgery group. Third, the associations between bariatric surgery and T2DM onset were examined by type of operation (LRYGB or LSG). All analyses were performed using SAS® version 9.4 (SAS Institute, Cary, NC, USA).

Results

A total of 1158 patients underwent laparoscopic LRYGB or LSG. There were 8385 potential controls with no history of bariatric surgery who had either been hospitalized with the diagnosis of obesity or who had a self-reported BMI of at least 35 kg/m^2 (Fig. 1). After excluding individuals with prevalent diabetes at baseline (221 in the bariatric surgery group and 903 controls, prevalence 19.3% and 10.8% respectively), each bariatric surgery case was matched with two non-surgery controls with the same propensity score, leaving only seven bariatric patients unmatched. None of these seven patients had new-onset T2DM during follow-up. The study group consisted of 917 patients who had MBS and 1811 matched controls (Table 1). There were no statistically significant differences between the two groups; there were over 90% women, mean age was 45 years, and half had a low SES.

During a median follow-up of 3.8 (range 0–9.0) years for the MBS group and 3.8 (range 0–9.0) years for the control group, altogether 179 patients were diagnosed with new-onset T2DM. New-onset T2DM was diagnosed in 164 of 1811 controls (9.1%) and in 15 of 917 patients who had bariatric surgery (1.6%) (Fig. 2). The rate of T2DM was 20.2 (95% c.i. 17.3 to 23.5) per 1000 person-years in the control group and 4.1 (2.5 to 6.9) per 1000 person-years in the bariatric surgery group; the RR for the bariatric group compared with the controls was 0.20 (0.12 to 0.35) and the corresponding RD was −16.1 (−19.8 to −12.3) per 1000 person-years. All new-onset T2DM after MBS occurred during the first 4 years, except in 1 patient after 8 years. In the control group, new-onset T2DM accumulated linearly (Fig. 2).

Figure 3 shows the results for subgroups of sex, age, and SES. The rate of new-onset T2DM was higher in men than in women in the bariatric surgery group and the controls, resulting in a lower relative risk among women. The RD was the same magnitude (−13.8 (−33.9 to 6.4) per 1000 person-years in men and −16.4 (−20.0 to −12.8) per 1000 person-years in women; $P_{interaction} = 0.803$). No statistically significant difference in the relative or absolute risk for T2DM after bariatric surgery between age groups was observed (interaction $P = 0.152$).

The risk reduction was greater for low SES (RR 0.10 (0.04 to 0.26) and RD −20.6 (−25.6 to −15.5) per 1000 person-years) compared with higher status (RR 0.35 (0.18 to 0.66) and RD −11.5 (−16.9 to −6.0) per 1000 person-years; $P_{interaction} = 0.017$). There were no statistically significant differences in baseline characteristics between patients who had MBS and controls in the low- and high-SES subgroups (Table S2). Comparing baseline characteristic between low- and high-SES controls, a higher proportion of those in the high-SES group were in employment and a higher proportion of those in the low-SES group had been granted disability retirement. There were no differences in baseline characteristics in patients who had LRYGB or LSG, such as age, co-morbidities, SES, retirement, or mean propensity score (Table S3).

The results of the sensitivity analyses with alternative matched control groups were similar to those of the main analyses (Figs 4 and S1). Compared with matched hospital controls, the relative risk of new-onset T2DM in the bariatric surgery group was 0.24 (0.13 to 0.46) and the RD was −11.1 (−15.9 to −6.2) per 1000 person-years. Compared with matched survey controls with a BMI of at least 40 kg/m^2 and those with a BMI between 35 and 35.9 kg/m^2, the risk reduction was more pronounced than that for hospital controls. Compared with survey controls with a BMI between 30 and 34.9 kg/m^2, the control group with the lowest diabetes risk, patients with bariatric surgery had a significantly reduced risk of new-onset T2DM (RR 0.54 (0.29 to 0.98) and RD −3.7 (−7.1 to −0.3) per 1000 person-years).

The sensitivity analysis with a 1-year lag before the start of the follow-up of new-onset T2DM also replicated the findings of the main analyses. Compared with matched controls, the RR among patients who had surgery was 0.16 (0.08 to 0.32) and the RD was −13.3 (−16.5 to −10.0) per 1000 person-years.

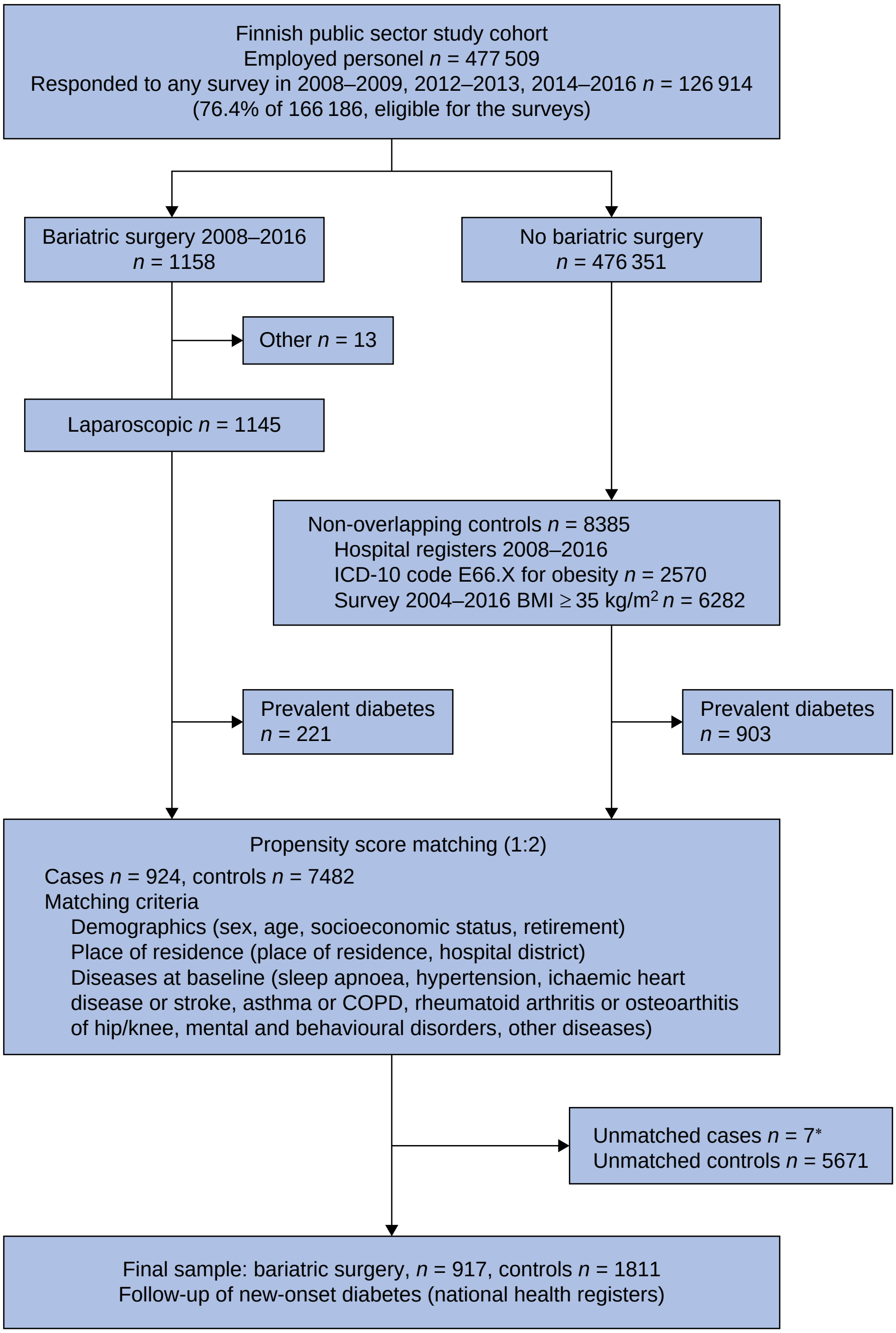

Fig. 1 Study flow chart

*No incident type 2 diabetes during follow-up. COPD, chronic obstructive pulmonary disease.

The sensitivity analysis examining the association between bariatric surgery and T2DM by the type of surgery found that both LSG (234 patients) and RYGBP (683) were equally effective in preventing T2DM. The RR and RD were 0.21 (0.08 to 0.57) and −15.9 (−21.1 to −10.7) per 1000 person-years, and 0.20 (0.11 to 0.37) and −16.1 (−20.0 to −12.2) per 1000 person-years respectively.

Discussion

This study identified a substantial risk reduction in developing new-onset T2DM associated with MBS compared with controls. There were no differences between men and women or age groups, but individuals of low SES benefited more from MBS than those of higher SES. The association with reduced risk of new-onset T2DM risk after MBS was substantial even in comparison to individuals with class I obesity.

These results are in agreement with those of a recent systematic review and meta-analysis[2] that included six heterogeneous population cohort studies[19–24] showing an association between bariatric surgery and reduced incidence of new-onset T2DM. Data on obesity in the control group were derived from hospital registers[20], measured BMI[21–24] or the information was missing[19]. The comparators in these studies were matched mainly by age,

Table 1 Baseline characteristics of propensity score-matched cohort of patients with bariatric surgery and controls

	Bariatric surgery (*n* = 917)	Controls (*n* = 1811)	*P*§
Sex			0.491
Male	81 (8.8)	146 (8.1)	
Female	836 (91.2)	1665 (91.9)	
Age (years), mean(s.d.)	44.8(9.6)	44.9(9.4)	0.757
Socioeconomic status			0.875
Low	465 (50.7)	936 (51.7)	
Intermediate	361 (39.4)	695 (38.4)	
Higher-grade non-manual	91 (9.9)	180 (9.9)	
Retirement status			0.212
Not retired	755 (82.3)	1525 (84.2)	
Disability retirement	157 (17.1)	282 (15.6)	
Statutory retirement	5 (0.6)	4 (0.2)	
Diseases			
Sleep apnoea	139 (15.2)	257 (14.2)	0.498
Hypertension	116 (13.0)	212 (11.7)	0.474
Cardiovascular diseases*	20 (2.2)	32 (1.8)	0.455
Asthma or COPDø	131 (14.3)	223 (12.3)	0.148
Musculoskeletal disorders†	108 (12.0)	203 (11.2)	0.659
Mental or behavioural disorders	71 (7.7)	138 (7.6)	0.910
Other‡	34 (3.7)	51 (2.8)	0.206
Place of residence			0.988
City	455 (49.6)	901 (49.8)	
Town	254 (27.7)	504 (27.8)	
Rural	208 (22.7)	406 (22.4)	
Hospital district			0.987
Helsinki and Uusimaa	347 (37.8)	691 (38.2)	
South-West Finland	146 (15.9)	280 (15.5)	
Pirkanmaa	151 (16.5)	307 (16.9)	
Northern Ostrobothnia	105 (11.5)	198 (10.9)	
Other	168 (18.3)	335 (18.5)	
Propensity score, mean(s.d.)	0.16(0.10)	0.16(0.09)	0.187¶

Values are *n* (%) unless indicated otherwise. *Ischaemic heart disease, heart failure, stroke. †Rheumatoid arhritis and related disorders, osteoarthritis of hip, osteoarthritis of knee. ‡Parkinson disease, multiple sclerosis, epilepsy, alcoholic liver disease, pancreatitis, renal failure. øCOPD, chronic obstructive pulmonary disease. §*P*-values derived from Chi^2 test for categorial variables and T-test for continous variables.

sex, and clinical characteristics[21,23]. One study[19] also controlled for education and another[24] for residential neighbourhood disadvantage. None of these studies included occupational status, which is another socioeconomic indicator known to be related to obesity and new-onset T2DM risk[29].

The present study adds to understanding of the ability of bariatric surgery to lower the risk of new-onset T2DM, particularly in individuals of low SES. This finding is not explained by the differences in baseline characteristics between MBS and control groups in low- or high-SES subgroups, or differences between low- and high-SES controls. Plausible explanations are multifactorial as people with individual or neighbourhood-level socioeconomic disadvantage may have an accumulation of risk factors and thus may experience a greater preventive effect of bariatric surgery in relation to new-onset T2DM risk. Low SES is a risk factor for a spectrum of interconnected mental and physical illnesses and health conditions, including obesity, T2DM, and other cardiometabolic disorders[29]. In addition, low SES has been found to be associated with worse access to healthcare, including MBS[26].

With obesity being a chronic disease, the risk of new-onset T2DM could be expected to increase with time and possible weight regain after MBS. However, most cases of T2DM in the present study occurred within the few first years after surgery. This finding is consistent with other studies[32–34] on new-onset T2DM risk after MBS during longer follow-up.

This study benefits from information on sociodemographic characteristics, occurrence and timing of the bariatric surgery, and major chronic co-morbidities based on linkage to reliable national registers. The incidence of new-onset T2DM was ascertained using these national health registers with virtually no loss to follow-up. Additional strengths include a matched control group based on a well balanced propensity score taking into account a wide set of potential confounders, including demographics, socioeconomic factors, clinical characteristics, and living environment features. The present study was conducted in a Scandinavian welfare country offering universal health care for all citizens, which diminishes biases from selection for treatment by, for example, SES.

However, the study has limitations. Among the patients who had MBS, greater or lesser weight loss might have been associated with a preventive effect on new-onset T2DM. Hence, the lack of data on bodyweight is a major limitation. Conversely, more weight loss may be an additional preventive factor for new-onset T2DM. This is supported by the sensitivity analyses, which showed that the relative benefit among patients who had MBS was highest in the group with a BMI of at least 40 kg/m^2 compared with the controls. In the main analysis, both survey-based BMI over 35 kg/m^2 and the ICD-10 code E66 for obesity were used to identify potential control patients. However, the code E66 may not always be recorded for patients with obesity needing other hospital care other than MBS or treatment of obesity-related co-morbidities. Therefore, alternative matched control groups based only on an E66 diagnosis or survey-based BMI categories were used for the analyses, but the results remained unchanged. Seven patients who had MBS were excluded because no potential controls with the same propensity score were available. However, none of these individuals developed T2DM during follow-up. In the matched controls who had not been treated in hospital for obesity, BMI was determined using self-reported height and weight, which was open to reporting bias. However, the cumulative hazard curves for new-onset T2DM followed a dose–response pattern in these self-reported survey controls between class I to III obesity, and the results did not differ from those observed among the matched hospital controls. This suggests that using self-reported data did not create an important bias[35]. It is possible that the patients who had MBS were more likely to be diagnosed with T2DM during active multidisciplinary treatment compared with the controls; this represents a potential ascertainment bias which could have led to an underestimation of the benefits of MBS in reducing T2DM risk during the first years of follow-up. The results of the analyses suggest that this bias, if anything, is small. The result of the sensitivity analysis using a minimum 1-year lag between the index date and new-onset T2DM was similar to that of the main analysis. Thus, undetected T2DM in the control group seems not to be an important source of underestimation. There was limited information on health-related behaviours, such as smoking or alcohol intake. This could have influenced the seeking of treatment and adherence to dietary recommendations after operation, and affected the risk of new-onset T2DM. However, information on hospitalizations for mental and behavioural disorders, which correlate with the use of addictive substances[29], was included in the propensity score. Finally, an ethnically homogeneous occupational cohort from a single welfare country

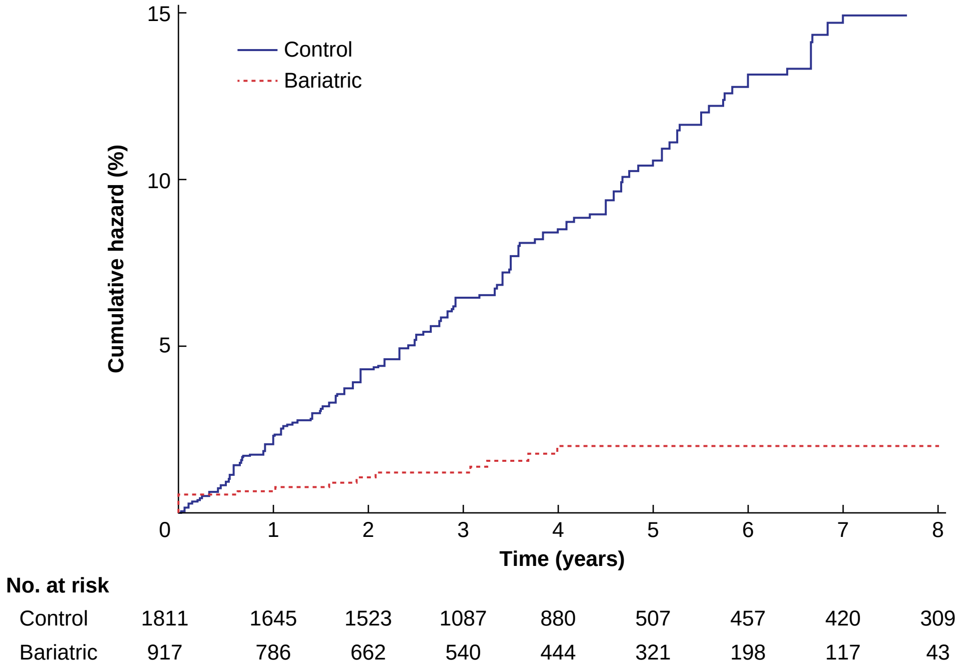

Fig. 2 Eight-year cumulative hazard of new-onset type 2 diabetes after metabolic bariatric surgery and in matched controls

Rate ratio 0.20 (95% c.i. 0.12 to 0.35), $P < 0.001$; rate difference –16.1 (–19.8 to –12.3) per 1000 person-years, $P < 0.001$.

		n	Events	RR	$P_{interaction}$	RD (per 1000 person-years)	$P_{interaction}$
All	Control	1811	164	0.20 (0.12,0.35)		–16.1 (–19.8,–12.3)	
	Bariatric	917	15				
Sex							
Male	Control	146	22	0.58 (0.23,1.42)	0.021	–13.8 (–33.9,6.4)	0.803
	Bariatric	81	6				
Female	Control	1665	142	0.14 (0.07,0.28)		–16.4 (–20.0,–12.8)	
	Bariatric	836	9				
Age (years)							
20–49	Control	1186	82	0.15 (0.07,0.35)	0.229	–13.4 (–17.3,–9.5)	0.152
	Bariatric	616	6				
50–75	Control	625	82	0.29 (0.15,0.58)		–20.0 (–28.0,–11.9)	
	Bariatric	301	9				
SES*							
Low	Control	936	94	0.10 (0.04,0.26)	0.023	–20.6 (–25.6 ,–15.5)	0.017
	Bariatric	465	4				
High	Control	875	70	0.35 (0.18,0.66)		–11.5 (–16.9,–6.0)	
	Bariatric	452	11				

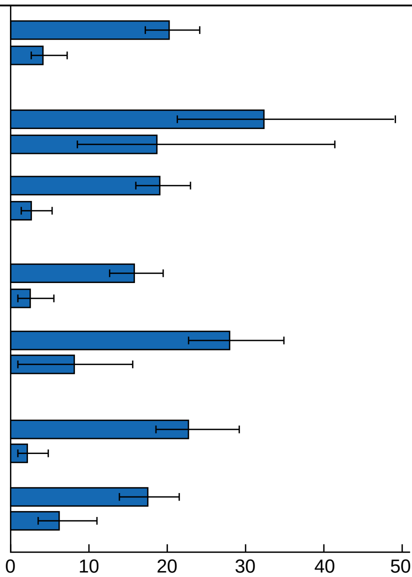

Fig. 3 Bariatric surgery and risk of new-onset type 2 diabetes compared with matched controls by patient subgroups

Values are *n* (%) unless otherwise indicated. Rates, rate ratios (RRs), and risk differences (RDs) are shown with 95% confidence intervals. Socioeconomic status (SES): low—basic educion, manual occupation, or residence in disadvantaged neighbourhood; high— all other combinations.

was used, and so further research is needed to examine the effect of bariatric surgery in non-white ethnic groups and among population segments outside the workforce.

Research is also needed to assess the effect of the new antiobesity medications (AOMs) on the risk of new-onset T2DM. The management of severe obesity should follow the principle of treatment of any chronic disease treatment with combination therapies. With the better availability of potent AOMs, the practice of combination therapy will grow as MBS and AOMs work in synergy on both the treatment of severe obesity and in enabling increased access to effective obesity treatment.

In conclusion, MBS was associated with a significantly reduced risk of new-onset T2DM and this preventive effect was most pronounced in individuals of low SES. These findings underline the importance of improving treatment accessibility for patients with severe obesity.

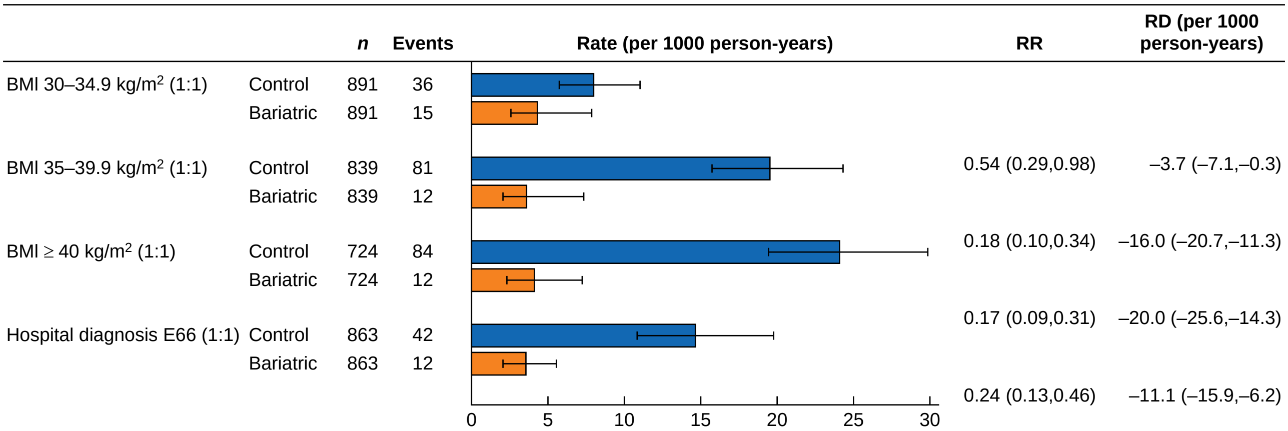

Fig. 4 **Bariatric surgery and risk of new-onset type 2 diabetes compared with alternative matched control groups**

Values are *n* (%) unless otherwise indicated. Rates, rate ratios (RRs), and risk differences (RDs) are shown with 95% confidence intervals.

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P.S. and J.V. contributed equally to this work.

Author contributions

Viiko Vahtera (Writing—original draft), Jukka Pajarinen (Writing—review & editing), Mika Kivimäki (Data curation, Writing—review & editing), Jenni Ervasti (Writing—review & editing), Jaana Pentti (Data curation, Writing—review & editing), Sari Stenholm (Supervision, Writing—review & editing), Jussi Vahtera (Data curation, Methodology, Supervision, Writing—review & editing), and Paulina Salminen (Supervision, Writing—review & editing)

Disclosure

P.S. reports lecture fees from Novo Nordisk. The authors declare no other conflict of interest.

Data availability

The pseudonymized questionnaire data used in the FPS study can be shared by request to the investigators after approval from the Finnish Institute of Occupational Health scientific committee. Linked electronic health records require separate permission from the National Institute of Health and Welfare and Statistics Finland.

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