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ORIGINAL CONTRIBUTIONS

The Socio-economic Impact of Bariatric Surgery

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Abstract
Introduction A recurring argument for bariatric surgery is cost savings due to sustained weight loss and reductions in comorbidities. However, studies prompting this argument tend to focus only on health care costs, and in some of them, cost changes after surgery have been modelled. The aim of this study was to generate real-world evidence on the socio-economic impact of bariatric surgery, by evaluating the effect on both direct and indirect costs.
Materials and Methods Using real-world data from national registries, predictions of health care costs, social transfer payments and income were performed for a surgically treated individual and compared to those for a similar but non-surgically treated individual 3 years before and after surgery. Secondly, the relative risks for health care costs, social transfer payments and income of a surgical group compared with a non-surgical group were estimated. The non-surgical group was defined as being eligible for bariatric surgery but not undergoing it.
Results Bariatric surgery was associated with higher, but insignificantly so, health care costs, primarily due to an increase in somatic inpatient services. A significant decrease in costs of drugs was seen, especially for anti-diabetic medication. Bariatric surgery had a slight positive effect on social transfer payments and no significant effect on income.
Conclusions There are no cost savings of bariatric surgery in the short run. Further real-world evidence over a longer period of time is needed to examine whether the higher health care costs will eventually be counterbalanced, making bariatric surgery a profitable intervention in a socio-economic perspective.

Keywords Bariatric surgery · Socio-economics · Economic evaluation · Real-world evidence · Health care costs

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Introduction

Obesity is an increasing burden for most societies due to its adverse health effects and associated costs. According to WHO, 20.7% of the male adult population and 17.4% of the female adult population in Denmark were defined as obese (BMI >30) in 2014 [1]. Obesity leads to increased morbidity and mortality and is thus associated with higher health care costs [2–21]. Bariatric surgery has been shown to cause sustained weight loss, which leads to a reduction in associated comorbidities as well as decreasing mortality rates [22–28]. Because bariatric surgery has positive implications for obesity-related risk factors and maintenance of weight loss, the question is whether this entails positive socio-economic implications as well. In this regard, previous research is not consistent [22, 28–36]. A widespread argument among proponents of bariatric surgery is future cost savings. However, most studies claiming this primarily focus on the patients' health care costs after surgery [22, 28–35, 37–43] and the potential return of investment [44–46]. Some results on health care cost savings are based on statistical models, Markov models and assumptions used to forecast outcomes of interest [25, 36, 47–50], which often do not take into account adverse effects and complications of the surgery. In addition, health care costs merely constitute a part of the total socio-economic impact, which emphasizes the need for examining other costs as well, e.g. costs associated with the labour market. In Denmark, the Danish Civil Registration System assigns every citizen a personal identification number (central personal registration [CPR] number), which allows for the linking of information between national registries at the individual level. This enables identification of people undergoing bariatric surgery and calculations of both direct and indirect costs associated with these individuals. Based on this real-world data, the current study seeks to evaluate the total socio-economic impact of bariatric surgery by estimating both direct and indirect costs before and after surgery among individuals undergoing bariatric surgery, compared with a group of individuals eligible for but not undergoing bariatric surgery.

Methods

Predictions of health care costs, social transfer payments and income were made for an individual undergoing bariatric surgery relative to a similar individual eligible for but not undergoing bariatric surgery. In addition, two regression analyses were performed. Both analyses compare a group of individuals undergoing bariatric surgery with a group of individuals eligible for but not undergoing bariatric surgery. The first analysis estimates the relative risk (RR) of the surgical group's health care costs relative to those of the non-surgical group before and after surgery. The second analysis estimates the RR of the surgical group's social transfer payments and income relative to the non-surgical group before and after surgery.

Population and Primary Measure

The population of the surgical group included individuals undergoing bariatric surgery in 2010. These individuals were identified using the National Patient Registry (NPR), which includes information on diagnosis and treatment procedures and other types of hospital contacts. The population of the non-surgical group did not undergo bariatric surgery but did meet the criteria for bariatric surgery at the time. In 2010, bariatric surgery in Denmark was offered to people from 18 years of age with (1) BMI >35 and diagnosed with at least one comorbidity or (2) BMI >40 [51]. In December 2010, the guidelines were revised specifying the comorbidities required for eligibility for surgery: type 2 diabetes (T2D), hypertension, dyslipidemia, sleep apnea, polycystic ovarian syndrome or arthrosis in the lower extremities [52]. Thus, these criteria defined the non-surgical group, and information on these comorbidities was retrieved from NPR. The upper age limit in both groups was 64 years—reflecting the ceiling of the labour force—and individuals aged 18–24 were excluded due to skewed age distributions and a low number of individuals in the two groups. BMI for the non-surgical group was calculated (kg/m^2) based on self-reported weight and height from the Danish National Health Profile, which is a national study of the Danish people's health based on questionnaire surveys and data from national registries [53].

According to the Danish Health Data Authority, 4280 of 4360 bariatric surgeries of people over 24 years old in 2010 were done by gastric bypass, whereas gastric banding and gastric sleeve only accounted for 70 and 10, respectively [54]. According to the guidelines at the time, further criteria for bariatric surgery were completion of a prior treatment at the hospital in addition to a weight reduction of 8% of the current body weight within 3–6 months prior to surgery [51].

Outcome Variables

Outcome variables included health care costs, social transfer payments and income. Health care costs were retrieved as total costs and in subcategories: somatic inpatient services, somatic outpatient services, primary health care and drugs. Furthermore, health care costs were divided between selected disease groups defined by the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10): diseases of the circulatory system, diseases of the digestive system, endocrine, nutritional and metabolic diseases, diseases of the musculoskeletal system and connective tissue and other diseases. Finally, drug costs were divided between selected drug codes defined according to the Anatomical Therapeutic Chemical (ATC) Classification System Index established by the WHO Collaborating Centre for Drug Statistics. Social transfer payments were retrieved as total costs and in subcategories: unemployment benefits, social security, disability pension, housing benefit, child benefit and sick pay. Income included annual earnings and other types of income not derived from the state. Because state education grants could not be separated from the data, this was included in income as well.

Information on all outcome variables was derived from national registries. Information on diagnoses and treatment was retrieved from NPR and linked with the Danish Case Mix System (diagnosis-related groups, DRG), which enabled calculation of the associated costs. Primary health care costs were derived from the Danish National Health Insurance Service Registry. Costs of drugs were calculated by multiplying the retail price for each drug with the prescribed quantity. This information is available from the Danish Medicines Agency. Information on income and social transfer payments was also derived from national registries from Statistics Denmark.

Data on all costs were traced retrospectively for the period 2007–2013, i.e. 3 years before and after surgery. The year of surgery (2010) is indicated as year 1, and the years in the preoperative and postoperative periods as years −3, −2 and

−1 and years 2, 3 and 4, respectively. When performing the predictions, costs were adjusted to 2014 price levels and converted to EUR (1 EUR = 7.43 DKK).

Covariates

Baseline characteristics were retrieved from the Danish Civil Registration System and Statistics Denmark and were used for adjustment in the regression analyses. Baseline characteristics comprised sex (male or female), age (in categories: 25–34, 35–44, 45–54 or 55–64 years), marital status (married/civil partnership or single) and education (primary school, high school, vocational education, short education, medium education, higher education or education unknown).

Analytical Model

The following equation was used to predict health care costs, social transfer payments and income, respectively, from the baseline characteristics:

$$Y_{\mathrm{i}} = \beta_0 + \beta_1 \times_{1\mathrm{i}} + \beta_2 \times_{2\mathrm{i}} + \ldots + \beta_k \times_{k\mathrm{i}} + \varepsilon_{\mathrm{i}}$$

The independent variables in the regression were surgery/non-surgery, sex, marital status, education and age.

In the regression analyses, a "One model GLM with link = log and gamma distribution" was used for the estimation of health care costs, social transfer payments and income [55]. All cost variables are left skewed, and a large proportion of them have costs equaling 0. Therefore, a gamma-distributed two-step model was used. Analyses were performed using SAS 9.1.3, and the significance level was set to 0.05.

Results

Population Characteristics

The surgical group and the non-surgical group included 3904 and 1549 individuals, respectively, and the mean ages were 41.6 and 52.3 years, respectively. The age distributions in the two groups can be seen in Table 1. In the surgical group, 77.5% were female, whereas females constituted 52.2% of the non-surgical group. Vocational education was the most frequent education level in both groups (45.6 and 41.7%, respectively), and the majority of individuals in both groups were married or in civil partnerships (69.7 and 71.6%, respectively). However, this association was not significant.

Predictions

Predictions of the yearly health care costs, social transfer payments and income were made for a 40-year-old, surgically treated male who is married or in a civil partnership and has a vocational education compared to those for a similar individual not undergoing bariatric surgery. The predictions are illustrated in Fig. 1 and the real numbers are presented in Table 2.

Three years prior to surgery, health care costs for the surgically treated man were approximately EUR 550 lower than those for the non-surgically treated man. One year before surgery, the costs for the surgically treated man reached the same level as for the non-surgically treated man, followed by a peak in year 1, reflecting the high costs associated with the surgery. In year 2, the surgically treated man had only slightly higher health care costs than the non-surgically treated man, and in the following 2 years, health care costs were similar for the two men. The costs of social transfer payments were slightly but non-significantly lower for the surgically treated man prior to surgery. Three years before surgery, the difference in costs was approximately EUR 400. For both men, social transfer payments increased up until surgery, after which the costs of the surgically treated man immediately started to decrease, whereas the costs for the non-surgically treated man continued to increase until year 2. Both men's costs continued to decrease throughout the period, ultimately resulting in approximately EUR 1600 lower costs for the surgically treated man in year 4. With regard to income, the surgically treated man had an income approximately EUR 5000 higher than the non-surgically treated man in year −3. The men's income followed roughly the same path of decrease up until surgery followed by a slight increase, resulting in an approximately EUR 6000 higher income for the surgically treated man in year 4.

In conclusion, our predictions indicate that bariatric surgery does not affect health care costs, that it has a slightly positive effect on social transfer payments and that it does not affect income notably.

Regression Analyses

Health Care Costs

Total health care costs were significantly lower in the surgical group in the preoperative period but higher in the postoperative period; see Table 3. However, estimates for the postoperative period were insignificant. The surgical group had lower costs for somatic inpatient services before surgery, but the postoperative period reflected higher costs among the surgically treated individuals, ending with 38% higher costs for somatic inpatient services in year 4. Costs of somatic outpatient services were higher in the surgical group 1 year before surgery, and the difference between the two groups decreased subsequently, resulting in 14% lower costs of outpatient services in the surgical group compared with the non-surgical group in year 4. Estimates of costs of primary health care were insignificant in the preoperative period but significantly lower

Table 1 Population characteristics

	Surgical group		Non-surgical group		*p* values
Number	3904		1549		
Age					
Mean, standard deviation	41.6	9.1	52.3	9.4	0.000
Distribution (*n*, %)					
25–34 years	962	24.6%	85	5.5%	0.000
35–44 years	1529	39.2%	243	15.7%	
45–54 years	1011	25.9%	468	30.2%	
55–64 years	402	10.3%	753	48.6%	
Sex (*n*, %)					
Male	879	22.5%	740	47.8%	0.000
Female	3025	77.5%	809	52.2%	
Marital status (*n*, %)					
Married/civil partnership	2722	69.7%	1109	71.6%	0.173
Single	1182	30.3%	440	28.4%	
Education (*n*, %)					
Primary school	1186	30.4%	562	36.3%	0.000
High school	165	4.2%	47	3.0%	
Vocational education	1780	45.6%	646	41.7%	
Short education	130	3.3%	47	3.0%	
Medium education	558	14.3%	172	11.1%	
Long education	48	1.2%	52	3.4%	
Education unknown	37	0.9%	23	1.5%	

in the surgical group after surgery, compared with the non-surgical group. Costs of drugs were lower in the surgical group during the whole period but significantly lower in the postoperative period (RR 0.49, RR 0.46 and RR 0.49, respectively).

Table 4 shows health care costs of specific disease groups. Costs of diseases of the circulatory system were lower in the surgical group during the whole period but notably lower in the postoperative period (RR 0.47, RR 0.47 and RR 0.37, respectively). The surgical group had 64% higher costs of diseases of the musculoskeletal system etc. 3 years before surgery and 31% lower costs in year 4. However, these costs already started to decrease in year −2, which complicates interpretation of the impact of the surgery on these costs. Costs of endocrine, nutritional and metabolic diseases where higher in the surgical group before surgery and the incremental costs increased additionally after surgery resulting in a RR of 7.76 in year 4. A similar tendency was seen in costs of diseases of the digestive system, which were lower in the surgical group prior to operation but subsequently exceeded the costs in the non-surgical group in year 4 (RR 2.71). Except for years 1 and 2, costs of other diseases were lower in the surgical group.

A decrease in costs was seen for the majority of ATC codes after surgery; see Table 5. Costs of code A, alimentary tract and metabolism; code A10, anti-diabetic medication; code M, musculoskeletal system and code R, respiratory system, were all higher for the surgical group in the preoperative period, but the costs in this group became significantly lower after surgery. Especially affected were costs of anti-diabetic medication; in year −3, the RR was 1.12 whereas in year 4, it was 0.07. Costs of code C, cardiovascular system, were lower for the surgical group in the preoperative period, but after the surgery, the RR decreased, resulting in 64% lower costs for this group in year 4. Except for year 2, costs of code H, systemic hormonal preparations etc., were also lower for the surgical group, both before and after surgery. Costs of other drugs were significantly lower for the surgical group in the preoperative period, but insignificantly higher in year 4.

All estimates in the analysis of health care costs were adjusted for age, sex, municipality and education.

Social Transfer Payments and Income

Costs of social transfer payments and income are shown in Table 6. The surgical group incurred lower total costs in the form of social transfer payments both before and after surgery, but the difference between the two groups was the greatest in the postoperative period (RR 0.79, 0.79 and 0.81, respectively). This was primarily due to a decrease in the difference in costs of unemployment benefits between the two groups

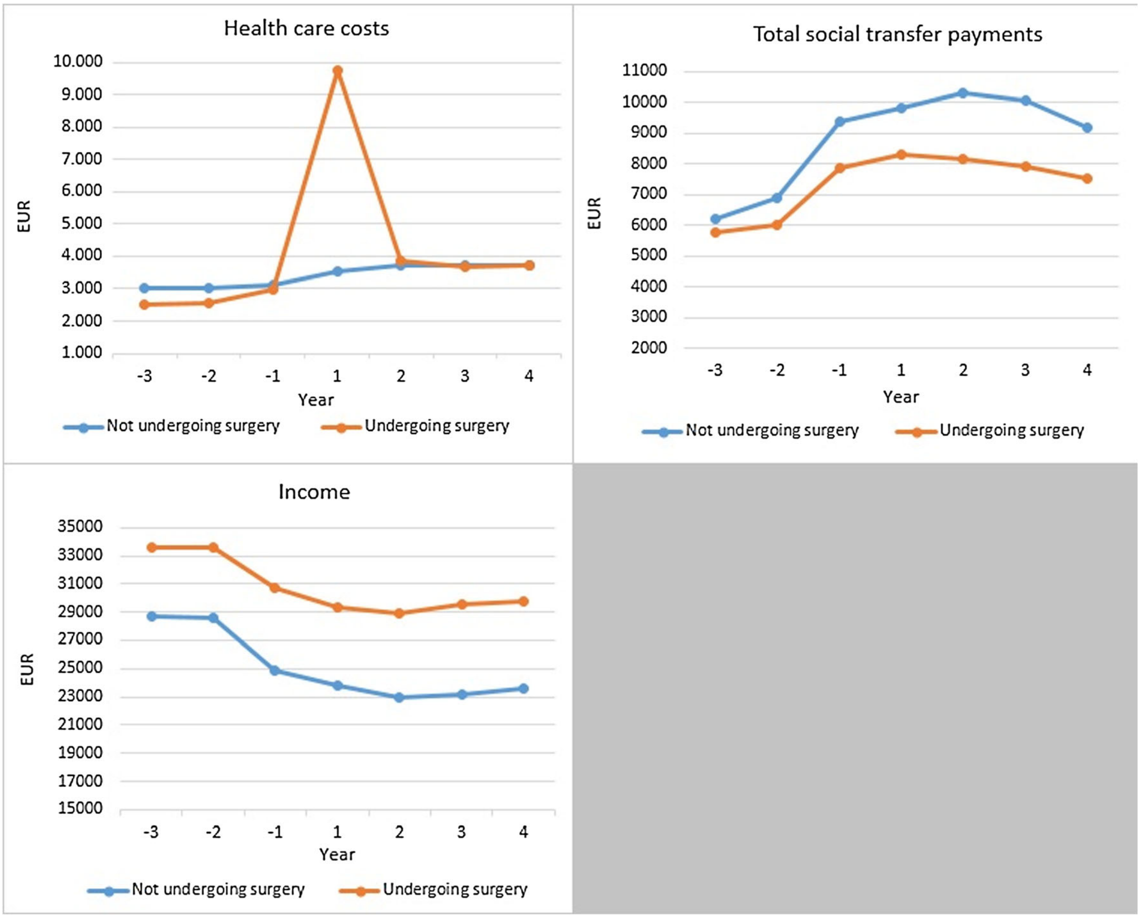

Fig. 1 Predictions of health care costs, social transfer payments and income of a surgically treated individual and a similar but non-surgically treated individual

resulting in significantly lower costs for the surgical group compared with the non-surgical group in year 4 (RR 0.65). In contrast, the surgical group had lower costs of social security in the preoperative period, but the difference between the two groups increased after surgery, resulting in significantly higher costs for the surgical group compared with the non-surgical group in year 4 (RR 1.34). Costs of disability pension were lower for the surgical group for the whole period but the lowest prior to surgery. Costs of housing benefit were higher in the surgical group both before and after surgery, but the incremental costs were lower after surgery (RR 1.36 in year 4). Costs of child benefit were also higher in the surgical group for the whole period, but the incremental costs were the highest in the postoperative period (RR 1.26, RR 1.27 and RR 1.26, respectively). The surgical group had higher costs of sick pay than the non-surgical group before surgery but lower costs in years 2 and 3 (2 and 9%, respectively). However, the difference in costs between the two groups

Table 2 Estimates of health care costs, social transfer payments and income of a surgically treated man and a non-surgically treated man

		Year						
		−3	−2	−1	1	2	3	4
Health care costs	Non-surgically treated	3,043	3,044	3,095	3,536	3,708	3,704	3,731
	Surgically treated	2,496	2,569	2,955	9,748	3,873	3,654	3,719
Social transfer payments	Non-surgically treated	6,203	6,906	9,367	9,846	10,330	10,054	9,176
	Surgically treated	5,784	5,999	7,897	8,303	8,188	7,929	7,520
Income	Non-surgically treated	28,699	28,643	24,896	23,824	22,965	23,200	23,575
	Surgically treated	33,669	33,621	30,771	29,412	28,913	29,534	29,751

Table 3 RR of health care costs in the surgical group compared with the non-surgical group

		Year						
		−3	−2	−1	1	2	3	4
Total health care costs	RR [95% CI]	0.82 [0.77; 0.88]	0.84 [0.79; 0.90]	0.95 [1.02; 0.18]	2.76 [2.57; 2.96]	1.04 [0.97; 1.12]	0.99 [0.92; 1.06]	1.07 [0.93; 1.07]
	p values	0.000	0.000	0.182	0.000	0.234	0.708	0.933
Somatic inpatient services	RR [95% CI]	0.68 [0.64; 0.74]	0.74 [0.69; 0.79]	0.61 [0.57; 0.66]	5.77 [5.37; 6.19]	1.56 [1.45; 1.68]	1.49 [1.39; 1.60]	1.38 [1.28; 1.49]
	p values	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Somatic outpatient services	RR [95% CI]	0.98 [0.91; 1.05]	1.04 [0.97; 1.11]	1.51 [1.41; 1.61]	0.87 [0.81; 0.93]	0.94 [0.87; 1.00]	0.79 [0.74; 0.85]	0.86 [0.80; 0.92]
	p values	0.511	0.320	0.000	0.000	0.065	0.000	0.000
Primary health care	RR [95% CI]	0.98 [0.91; 1.05]	0.94 [0.87; 1.00]	1.05 [0.98; 1.12]	0.90 [0.85; 0.97]	0.86 [0.81; 0.93]	0.79 [0.74; 0.85]	0.83 [0.78; 0.89]
	p values	0.500	0.062	0.173	0.004	0.000	0.000	0.000
Drugs	RR [95% CI]	0.84 [0.79; 0.90]	0.80 [0.75; 0.86]	0.89 [0.83; 0.95]	0.51 [0.48; 0.55]	0.49 [0.46; 0.53]	0.46 [0.43; 0.49]	0.49 [0.46; 0.53]
	p values	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4 RR of costs of selected disease groups in the surgical group compared with the non-surgical group

		Year						
		−3	−2	−1	1	2	3	4
Diseases of the circulatory system	RR [95% CI]	0.89 [0.83; 0.96]	0.49 [0.46; 0.52]	0.58 [0.54; 0.62]	0.40 [0.37; 0.43]	0.47 [0.44; 0.51]	0.47 [0.44; 0.51]	0.37 [0.35; 0.40]
	p values	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Diseases of the digestive system	RR [95% CI]	0.48 [0.45; 0.51]	0.70 [0.65; 0.75]	0.67 [0.63; 0.72]	2.73 [2.55; 2.93]	3.71 [3.44; 4.00]	4.18 [3.92; 4.45]	2.71 [2.53; 2.91]
	p values	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Endocrine, nutritional and metabolic diseases	RR [95% CI]	1.37 [1.28; 1.47]	1.50 [1.40; 1.60]	5.37 [5.02; 5.74]	1.43 [1.26; 1.44]	2.76 [2.56; 2.97]	5.31 [4.95; 5.69]	7.76 [7.19; 8.38]
	p values	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Diseases of the musculoskeletal system and connective tissue	RR [95% CI]	1.64 [1.52; 1.77]	0.89 [0.83; 0.95]	0.84 [0.78; 0.90]	0.79 [0.74; 0.85]	0.91 [0.85; 0.97]	0.80 [0.75; 0.86]	0.69 [0.64; 0.74]
	p values	0.000	0.001	0.000	0.000	0.004	0.000	0.000
Other diseases	RR [95% CI]	0.71 [0.66; 0.88]	0.88 [0.82; 0.95]	0.75 [0.70; 0.80]	1.13 [1.05; 1.21]	1.18 [1.09; 1.26]	0.86 [0.80; 0.92]	0.96 [0.90; 1.04]
	p values	0.000	0.000	0.000	0.001	0.000	0.000	0.308

Table 5 RR of costs of selected ATC codes in the surgical group compared with the non-surgical group

		Year						
		−3	−2	−1	1	2	3	4
A: alimentary tract and metabolism	RR [95% CI]	1.10 [1.03; 1.18]	0.95 [0.89; 1.02]	1.04 [0.97; 1.11]	0.47 [0.44; 0.50]	0.52 [0.49; 0.56]	0.54 [0.50; 0.58]	0.63 [0.59; 0.67]
	p values	0.005	0.157	0.312	0.000	0.000	0.000	0.000
A10: anti-diabetic medication	RR [95% CI]	1.12 [1.05; 1.19]	1.26 [1.18; 1.35]	1.28 [1.20; 1.36]	0.09 [0.09; 0.10]	0.07 [0.07; 0.08]	0.05 [0.05; 0.06]	0.07 [0.06; 0.07]
	p values	0.001	0.000	0.000	0.000	0.000	0.000	0.000
C: cardiovascular system	RR [95% CI]	0.85 [0.80; 0.91]	0.76 [0.72; 0.81]	0.80 [0.75; 0.86]	0.38 [0.36; 0.41]	0.32 [0.30; 0.34]	0.31 [0.29; 0.33]	0.36 [0.34; 0.38]
	p values	0.000	0.000	0.000	0.000	0.000	0.000	0.000
H: systemic hormonal preparations etc.	RR [95% CI]	0.64 [0.60; 0.69]	0.82 [0.77; 0.88]	0.90 [0.84; 0.96]	0.79 [0.74; 0.84]	1.12 [1.04; 1.20]	0.78 [0.73; 0.83]	0.82 [0.77; 0.88]
	p values	0.000	0.000	0.001	0.000	0.003	0.000	0.000
M: musculoskeletal system	RR [95% CI]	1.13 [1.06; 1.21]	1.06 [0.99; 1.13]	1.12 [1.05; 1.19]	0.66 [0.62; 0.70]	0.58 [0.54; 0.62]	0.69 [0.65; 0.74]	0.81 [0.74; 0.86]
	p values	0.000	0.103	0.001	0.000	0.000	0.000	0.000
R: respiratory system	RR [95% CI]	1.16 [1.08; 1.24]	1.05 [0.98; 1.12]	0.97 [0.91; 1.04]	0.55 [0.52; 0.60]	0.49 [0.45; 0.52]	0.47 [0.44; 0.51]	0.51 [0.47; 0.55]
	p values	0.000	0.177	0.432	0.000	0.000	0.000	0.000
Other drugs	RR [95% CI]	0.74 [0.69; 0.79]	0.70 [0.65; 0.75]	0.81 [0.75; 0.86]	0.85 [0.79; 0.90]	0.87 [0.81; 0.93]	0.95 [0.89; 1.02]	1.07 [1.00; 1.14]
	p values	0.000	0.000	0.000	0.000	0.000	0.132	0.064

Table 6 RR for change in social transfer payments and income in the surgical group compared with the non-surgical group

		Year						
		−3	−2	−1	1	2	3	4
Total social transfer payments	RR [95% CI]	0.93 [0.87; 1.00]	0.87 [0.81; 0.93]	0.84 [0.78; 0.91]	0.84 [0.79; 0.90]	0.79 [0.74; 0.85]	0.79 [0.73; 0.85]	0.82 [0.76; 0.88]
	p values	0.057	0.000	0.000	0.000	0.000	0.000	0.000
Unemployment benefits	RR [95% CI]	1.06 [0.99; 1.14]	1.17 [1.09; 1.26]	0.97 [0.91; 1.04]	1.04 [0.98; 1.12]	0.92 [0.86; 0.99]	0.71 [0.67; 0.76]	0.65 [0.60; 0.69]
	p values	0.088	0.000	0.429	0.218	0.021	0.000	0.000
Social security	RR [95% CI]	0.95 [1.89; 1.02]	0.85 [0.79; 0.91]	0.96 [0.90; 1.03]	1.05 [0.98; 1.03]	1.20 [1.11; 1.28]	1.41 [1.31; 1.51]	1.34 [1.23; 1.44]
	p values	0.196	0.000	0.287	0.161	0.000	0.000	0.000
Disability pension	RR [95% CI]	0.64 [0.60; 0.69]	0.63 [0.59; 0.67]	0.67 [0.63; 0.71]	0.80 [0.75; 0.86]	0.79 [0.74; 0.84]	0.76 [0.72; 0.82]	0.72 [0.67; 0.77]
	p values	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Housing benefit	RR [95% CI]	1.77 [1.65; 1.91]	1.57 [1.45; 1.68]	1.67 [1.54; 1.80]	1.52 [1.41; 1.64]	1.40 [1.40; 1.51]	1.71 [1.59; 1.85]	1.36 [1.27; 1.47]
	p values	0.000	0.000	0.000	0.571	0.007	0.000	0.000
Child benefit	RR [95% CI]	1.10 [1.02; 1.18]	1.38 [1.29; 1.47]	1.40 [1.31; 1.50]	1.06 [0.99; 1.14]	1.24 [1.16; 1.32]	1.32 [1.23; 1.41]	1.46 [1.37; 1.56]
	p values	0.009	0.000	0.000	0.113	0.000	0.000	0.000
Sick pay	RR [95% CI]	1.35 [1.26; 1.45]	1.54 [1.144; 1.66]	1.26 [1.18; 1.36]	0.98 [0.91; 1.05]	0.91 [0.85; 0.97]	0.86 [0.80; 0.92]	1.33 [1.24; 1.43]
	p values	0.000	0.000	0.000	0.571	0.007	0.000	0.000
Income	RR [95% CI]	1.17 [1.10; 1.26]	1.17 [1.10; 1.26]	1.24 [1.16; 1.32]	1.23 [1.16; 1.32]	1.26 [1.18; 1.35]	1.27 [1.19; 1.36]	1.26 [1.18; 1.35]
	p values	0.000	0.000	0.000	0.000	0.000	0.000	0.000

returned to the same level as 3 years before surgery (RR 1.33 and RR 1.35 respectively). Finally, the surgical group had a significantly higher income than the non-surgical group both before and after surgery. The excess income was slightly higher in year 4 (RR 1.26), but the increase in RR from year −3 to year 4 was not significant. In addition, the primary increase commenced before surgery, which renders the picture of bariatric surgery's impact on this parameter unclear.

All estimates were adjusted for age, sex, municipality and education.

Discussion

In this study, we have generated real-world evidence on the direct and indirect costs associated with obese individuals undergoing bariatric surgery compared with a group of individuals eligible for but not undergoing bariatric surgery. To our knowledge, we are the first to conduct a registry-based study evaluating the impact of bariatric surgery on both direct and indirect costs over a 7-year period. Our predictions indicated that bariatric surgery did not affect health care costs, induced slightly lower costs of social transfer payments and led to no notable change in income. These findings were partly confirmed in the regression analyses, which indicated higher health care costs, slightly lower costs of social transfer payments and no significant impact on income. In conclusion, our regression analyses did not demonstrate any net cost savings of bariatric surgery during the period of analysis. However, we identified some notable effects of bariatric surgery on some of the subcategories.

The use of national registries for retrieving real-world data from the preoperative and postoperative periods allowed us to look back and ahead from the time of surgery and thereby evaluate the impact of the surgery on health care costs, social transfer payments and income at the individual level. By including all types of costs and dividing them into subcategories, we were able to identify the parameters on which bariatric surgery had or did not have an effect. With regard to health care costs, especially costs of somatic inpatient services and costs of drugs were affected. Costs of somatic inpatient services were significantly higher in the surgical group, whereas costs of drugs were significantly lower in the surgical group after surgery. Particularly code A10, anti-diabetic medication, was affected, the costs for this going from being 12% higher in the surgical group in year −3 to being 93% lower in year 4. In year −1, somatic inpatient services have decreased and somatic outpatient services decreased, which may be a result of the criteria for surgery: Somatic inpatient services may have decreased due to the 8% weight reduction and somatic outpatient services may have increased due to the treatment prior to surgery including frequent medical examinations.

Although our results on health care costs in the postoperative period are insignificant, increased health care costs after bariatric surgery have been identified in other studies, especially increases in costs of inpatient services and medical expenses, which is in line with our findings [22, 30, 31, 33–35, 37, 38, 42, 44]. For instance, Lopes et al. [56] conclude in their meta-analysis that bariatric surgery was associated with an average reduction in drug costs of 49.8% during a postoperative period of 6–72 months. Our finding of a significant decrease in drug costs is primarily due to the notable reduction in drug code A10, anti-diabetic medication. This supports previous findings of bariatric surgery resulting in improvement or remission of T2D [22–24, 26, 27, 56, 57]. The decrease in costs of diseases of the circulatory system is due to reductions in the prevalence of comorbidities, e.g. hypertension, ischemic heart disease and stroke [3, 4, 6]. The higher costs of endocrine, nutritional and metabolic diseases and diseases of the digestive system are probably indications of complications of the surgery, e.g. nutritional deficiencies and other gastrointestinal complications [24, 58–61]. Already in year −1, diseases of the circulatory system, diseases of the musculoskeletal system and other diseases have decreased in the surgical group, which may be explained by the required weight reduction prior to surgery.

Our findings underline the notable positive effect of bariatric surgery on T2D in addition to some circulatory diseases. However, in a socio-economic perspective, these beneficial effects are outweighed by other complications indicated by the increase of endocrine, nutritional and metabolic diseases and in diseases of the digestive system.

In the analysis of social transfer payments, we identified significantly lower costs of unemployment benefits and significantly higher costs of social security. These results can be explained by a displacement of costs due to expiry of the unemployment benefit period. Income was affected by a small increase, though the primary increase was identified prior to surgery, which makes the picture of income unclear. The weight reduction prior to operation might also contribute to this finding, i.e. improved ability to work supported by the decrease in sick pay from year −3 to year −1. Obesity has been associated with reproductive disorders and complications [6, 62], which supports our finding of significantly higher costs of child benefit in the postoperative period, indicating that the weight loss achieved by the surgery induces an increased fertility rate among female patients.

The fact that we did not identify any net savings does not mean that bariatric surgery should be considered ineffective. The increase in health care costs, primarily due to complications and adverse effects of the surgery, should be weighed against the beneficial impact of bariatric surgery, including positive clinical effects, as indicated by our results (e.g. reductions in the prevalence of T2D and circulatory diseases, and reduced drug use) in addition to considerable and sustained weight loss [27, 43, 57, 60, 63], enhanced quality of life [25, 64–68] and a small decrease in total social transfer payments, as found in our study. In line with the statement made by Agren et al., expressing that increased hospital care is a moderate price to pay considering the well-documented benefits of bariatric surgery [32], the present argument for bariatric surgery as applied weight loss intervention should not be based on possible cost savings, but rather on the potential improved quality of life and clinical benefits. According to the Danish health legislation, the argument for (carrying out) health care services are clinical benefits but in the public debate, clinical benefit is often considered equal to economic benefit, though this is not statutory. Likewise, the argument for bariatric surgery is often cost savings and the endpoint of improving health and quality of life fades into the background. However, these clinical benefits may entail economic benefit in the longer run if improved health of the surgically treated individuals leads to improved ability to work, fewer hospital contacts etc. The period of analysis in the current study is obviously not long enough to reveal whether bariatric surgery induces cost savings in the longer run. The identified increase in costs of somatic inpatient services actually seemed to ease off slightly during the postoperative period, which indicates that these costs might be counterbalanced over a longer period. However, studies on the economic impact of bariatric surgery over longer periods of time are limited. Most studies with long time horizons are based on different types of statistical modelling and forecasting methods, which often do not capture the dynamics and complexities in terms of, for instance, complications and comorbidities, which is possible when using real-world data. Weiner et al. conducted a study of health care costs of surgically treated individuals relative to a matched non-surgical group, in which they found an increase in total health care costs for the surgical group, even 6 years after operation [34]. In contrast, the Swedish Obese Subjects (SOS) study on health care use over 20 years after bariatric surgery has demonstrated that costs of inpatient and non-primary outpatient services among surgically treated obese individuals only exceeded the costs for conventionally treated control subjects in the first 6 years after surgery [41]. However, it should be noted that the surgical population of the SOS study was primarily treated with vertical-banded gastroplasty, whereas gastric bypass was the customary procedure in Denmark in 2010, which complicates a proper comparison. Nevertheless, the results from the SOS study indicate that bariatric surgery has the potential to induce reductions in health care costs in the long run. With regard to social transfer payments, the direction of these costs is more unclear. We tend to assume that the correlation between obesity and higher social transfer payments is evidence of a causal effect, i.e. when the obese individuals lose weight, they will return to the labour market. However, this may not be the case and, thus, public resources will not necessarily be as strongly affected as expected.

Taken together, these results emphasize the need for further research using real-world evidence on both direct and indirect costs over longer periods of time instead of modelled estimates, in order to examine the actual socio-economic impact of bariatric surgery.

Limitations

Even though the non-surgical group was defined by criteria that also applied to the surgical group, it should be noted that the two groups are not identical and this shortcoming should be acknowledged. It appears from Table 1 that the individuals in the surgical group were younger than those in the non-surgical group. Also, the surgical group mainly consisted of women, whereas this was not the case in the non-surgical group. However, the discrepancies between the two groups have been taken into account by adjusting all estimates in the regression analyses. In addition, our results elucidate that the surgical group initially had more sick days than the non-surgical group and higher costs of drugs in some ATC codes. This indicates that this group might already be in worse condition than the non-surgical group. Furthermore, bariatric surgery is followed by some recommendations concerning diet and exercise but we have no data on compliance in this matter. Neither do we know the magnitude of BMI reduction due to surgery and whether this reduction is sustained in the years following operation. Taken together, the difference between the surgical group and non-surgical group and the lack of information on BMI reduction and postoperative lifestyle could explain some of the estimates in the regression analyses, e.g. some of the results on comorbidities after surgery.

Conclusion

In this study, we used real-world data to conclude that bariatric surgery had a slight positive effect on social transfer payments, had no significant effect on income and did not induce lower health care costs 3 years after surgery. Taken together, no net saving is gained from bariatric surgery in the short run. The present argument for bariatric surgery should be based on the beneficial clinical effects, sustained weight loss and improved quality of life rather than on the potential of saving public resources. Further real-world evidence on direct and indirect costs over a long period of time is needed to examine if costs eventually will be counterbalanced and thereby making bariatric surgery a socio-economically beneficial intervention.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethics The study was reported to the Danish Data Protection Agency. Because the study neither involved biological material nor any form of intervention but merely register data, there was no need for an ethical approval under the Committee Act.

Statement of Informed Consent The study was approved by the Danish Data Protection Agency. Because the study only involved register data and no interventions or biological material, no ethical approval was required.

Statement of Human and Animal Rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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References

1. World Health Organization (WHO). Global Health Observatory data repository. Obesity (body mass index ≥30),age-standardized (%). Estimates by country [database on the Internet]. [Internet]. 2017 cited 2017 May 3] Available from: http://apps.who.int/gho/data/view.main.CTRY2450A?lang=en.
2. Finkelstein EA, Fiebelkorn IC, Wang G. State-level estimates of annual medical expenditures attributable to obesity. Obes Res. 2004;12(1):18–24.
3. Field AE, Coakley EH, Must A, et al. Impact of overweight on the risk of developing common chronic diseases during a 10-year period. Arch Intern Med. 2001;161(13):1581–6.
4. Haslam DW, James WP. Obesity. Lancet. 2005;366(9492):1197–209.
5. Visscher TL, Seidell JC. The public health impact of obesity. Annu Rev Public Health. 2001;22:355–75.
6. Branca F. The challenge of obesity in the WHO European region and the strategies for response: EURO nonserial publication. Branca F, Lobstein T, Nikogosian H, Nikogosian H, World Health Organization, editors.; 2007.
7. Pi-Sunyer FX. Medical hazards of obesity. Ann Intern Med. 1993;119(7 Pt 2):655–60.
8. Bigaard J, Tjonneland A, Thomsen BL, et al. Waist circumference, BMI, smoking, and mortality in middle-aged men and women. Obes Res. 2003;11(7):895–903.
9. Colditz GA. Economic costs of obesity. Am J Clin Nutr. 1992;55(2 Suppl):503S–7S.
10. Colditz GA. Economic costs of obesity and inactivity. Med Sci Sports Exerc. 1999;31(11 Suppl):S663–7.
11. Katzmarzyk PT, Janssen I. The economic costs associated with physical inactivity and obesity in Canada: an update. Can J Appl Physiol. 2004;29(1):90–115.
12. Levy E, Levy P, Le Pen C, et al. The economic cost of obesity: the French situation. Int J Obes Relat Metab Disord. 1995;19(11):788–92.
13. Pronk NP, Goodman MJ, O'Connor PJ, et al. Relationship between modifiable health risks and short-term health care charges. JAMA. 1999;282(23):2235–9.
14. Schmid A, Schneider H, Golay A, et al. Economic burden of obesity and its comorbidities in Switzerland. Soz Praventivmed. 2005;50(2):87–94.
15. Segal L, Carter R, Zimmet P. The cost of obesity: the Australian perspective. PharmacoEconomics. 1994;5(Suppl 1):45–52.
16. Swinburn B, Ashton T, Gillespie J, et al. Health care costs of obesity in New Zealand. Int J Obes Relat Metab Disord. 1997;21(10):891–6.
17. Tucker LA, Clegg AG. Differences in health care costs and utilization among adults with selected lifestyle-related risk factors. Am J Health Promot. 2002;16(4):225–33.
18. Wolf AM, Colditz GA. Current estimates of the economic cost of obesity in the United States. Obes Res. 1998;6(2):97–106.
19. Wolf AM, Colditz GA. The cost of obesity: the US perspective. PharmacoEconomics. 1994;5(Suppl 1):34–7.
20. Andreyeva T, Sturm R, Ringel JS. Moderate and severe obesity have large differences in health care costs. Obes Res. 2004;12(12):1936–43.
21. Finkelstein EA, Fiebelkorn IC, Wang G. National medical spending attributable to overweight and obesity: how much, and who's paying? Health Aff (Millwood). Suppl Web Exclusives. 2003;W3:219–26.
22. Sussenbach SP, Padoin AV, Silva EN, et al. Economic benefits of bariatric surgery. Obes Surg. 2012;22(2):266–70.
23. Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. JAMA. 2004;292(14):1724–37.
24. Gloy VL, Briel M, Bhatt DL, et al. Bariatric surgery versus non-surgical treatment for obesity: a systematic review and meta-analysis of randomised controlled trials. BMJ. 2013;347:f5934.
25. Wang BC, Wong ES, Alfonso-Cristancho R, et al. Cost-effectiveness of bariatric surgical procedures for the treatment of severe obesity. Eur J Health Econ. 2014;15(3):253–63.
26. Arterburn DE, Courcoulas AP. Bariatric surgery for obesity and metabolic conditions in adults. BMJ. 2014;349:g3961.
27. Courcoulas AP, Yanovski SZ, Bonds D, et al. Long-term outcomes of bariatric surgery: a national institutes of health symposium. JAMA Surg. 2014;149(12):1323–9.
28. Broderick RC, Fuchs HF, Harnsberger CR, et al. Increasing the value of healthcare: improving mortality while reducing cost in bariatric surgery. Obes Surg. 2015;25(12):2231–8.
29. Christou NV, Sampalis JS, Liberman M, et al. Surgery decreases long-term mortality, morbidity, and health care use in morbidly obese patients. Ann Surg. 2004;240(3):416,23. discussion 423-4
30. Monk Jr JS, Dia Nagib N, Stehr W. Pharmaceutical savings after gastric bypass surgery. Obes Surg. 2004;14(1):13–5.
31. Hodo DM, Waller JL, Martindale RG, et al. Medication use after bariatric surgery in a managed care cohort. Surg Obes Relat Dis. 2008;4(5):601–7.
32. Agren G, Narbro K, Jonsson E, et al. Cost of in-patient care over 7 years among surgically and conventionally treated obese patients. Obes Res. 2002;10(12):1276–83.
33. Kelles SM, Barreto SM, Guerra HL. Costs and usage of healthcare services before and after open bariatric surgery. Sao Paulo Med J. 2011;129(5):291–9.
34. Weiner JP, Goodwin SM, Chang HY, et al. Impact of bariatric surgery on health care costs of obese persons: a 6-year follow-up of surgical and comparison cohorts using health plan data. JAMA Surg. 2013;148(6):555–62.
35. Bruschi Kelles SM, Machado CJ, Barreto SM. Before-and-after study: does bariatric surgery reduce healthcare utilization and related costs among operated patients? Int J Technol Assess Health Care. 2015;31(6):407–13.
36. Chang SH, Stoll CR, Colditz GA. Cost-effectiveness of bariatric surgery: should it be universally available? Maturitas. 2011;69(3):230–8.
37. Keating C, Neovius M, Sjoholm K, et al. Health-care costs over 15 years after bariatric surgery for patients with different baseline glucose status: results from the Swedish obese subjects study. Lancet Diabetes Endocrinol. 2015;3(11):855–65.

38. Zingmond DS, McGory ML, Ko CY. Hospitalization before and after gastric bypass surgery. JAMA. 2005;294(15):1918–24.
39. Hoerger TJ, Zhang P, Segel JE, et al. Cost-effectiveness of bariatric surgery for severely obese adults with diabetes. Diabetes Care. 2010;33(9):1933–9.
40. Narbro K, Jonsson E, Larsson B, et al. Economic consequences of sick-leave and early retirement in obese Swedish women. Int J Obes Relat Metab Disord. 1996;20(10):895–903.
41. Neovius M, Narbro K, Keating C, et al. Health care use during 20 years following bariatric surgery. JAMA. 2012;308(11):1132–41.
42. Nguyen NT, Varela JE, Sabio A, et al. Reduction in prescription medication costs after laparoscopic gastric bypass. Am Surg. 2006;72(10):853–6.
43. Padwal R, Klarenbach S, Wiebe N, et al. Bariatric surgery: a systematic review of the clinical and economic evidence. J Gen Intern Med. 2011;26(10):1183–94.
44. Klein S, Ghosh A, Cremieux PY, et al. Economic impact of the clinical benefits of bariatric surgery in diabetes patients with BMI ≥35 kg/m^2. Obesity (Silver Spring). 2011;19(3):581–7.
45. Cremieux PY, Buchwald H, Shikora SA, et al. A study on the economic impact of bariatric surgery. Am J Manag Care. 2008;14(9):589–96.
46. Sampalis JS, Liberman M, Auger S, et al. The impact of weight reduction surgery on health-care costs in morbidly obese patients. Obes Surg. 2004;14(7):939–47.
47. Song HJ, Kwon JW, Kim YJ, et al. Bariatric surgery for the treatment of severely obese patients in South Korea—is it cost effective? Obes Surg. 2013;23(12):2058–67.
48. Maklin S, Malmivaara A, Linna M, et al. Cost-utility of bariatric surgery for morbid obesity in Finland. Br J Surg. 2011;98(10):1422–9.
49. Campbell J, McGarry LA, Shikora SA, et al. Cost-effectiveness of laparoscopic gastric banding and bypass for morbid obesity. Am J Manag Care. 2010;16(7):e174–87.
50. Faria GR, Preto JR, Costa-Maia J. Gastric bypass is a cost-saving procedure: results from a comprehensive Markov model. Obes Surg. 2013;23(4):460–6.
51. Expert Panel, the National Board of Health. Fællesprotokol for kirurgisk behandling af svær fedme i Danmark. 2008.
52. Indenrigs- og Sundhedsministeriet, Danske Regioner. Retningslinjer for visitation og henvisning på fedmeområdet. 2010.
53. The National Board of Health, The National Institute of Public Health, University of Southern Denmark. Danskernes sundhed. Tal fra Den Nationale Sundhedsprofil [Internet].
54. The Danish Health Data Authority. Statement of bariatric surgeries. [Internet]. Available from: http://esundhed.dk/sundhedsregistre/fedmeoperationer01/Sider/FOP001.aspx.
55. Buntin MB, Zaslavsky AM. Too much ado about two-part models and transformation? Comparing methods of modeling medicare expenditures. J Health Econ. 2004;23(3):525–42.
56. Lopes EC, Heineck I, Athaydes G, et al. Is bariatric surgery effective in reducing comorbidities and drug costs? A systematic review and meta-analysis. Obes Surg. 2015;25(9):1741–9.
57. Picot J, Jones J, Colquitt JL, Gospodarevskaya E, Loveman E, Baxter L, Clegg EJ. The clinical effectiveness and cost-effectiveness of bariatric (weight loss) surgery for obesity: a systematic review and economic evaluation. Health Technology Assessment. 2009;13(41).
58. Encinosa WE, Bernard DM, Du D, et al. Recent improvements in bariatric surgery outcomes. Med Care. 2009;47(5):531–5.
59. Maggard MA, Shugarman LR, Suttorp M, et al. Meta-analysis: surgical treatment of obesity. Ann Intern Med. 2005;142(7):547–59.
60. Sjostrom L. Review of the key results from the Swedish Obese Subjects (SOS) trial—a prospective controlled intervention study of bariatric surgery. J Intern Med. 2013;273(3):219–34.
61. Finks JF, Kole KL, Yenumula PR, et al. Michigan Bariatric Surgery Collaborative, from the Center for Healthcare Outcomes and Policy. Predicting risk for serious complications with bariatric surgery: results from the Michigan Bariatric Surgery Collaborative. Ann Surg. 2011;254(4):633–40.
62. Broughton DE, Moley KH. Obesity and female infertility: potential mediators of obesity's impact. Fertil Steril 2017 11.
63. Adams TD, Davidson LE, Litwin SE, et al. Health benefits of gastric bypass surgery after 6 years. JAMA. 2012;308(11):1122–31.
64. Monteiro F, Ponce DA, Silva H, Pitta F, Carrilho AJ. Physical function, quality of life, and energy expenditure during activities of daily living in obese, post-bariatric surgery, and healthy subjects. Obes Surg 2017 6.
65. Busetto L, Mozzi E, Schettino AM, et al. Italian Group for Lap-Band. Three years durability of the improvements in health-related quality of life observed after gastric banding. Surg Obes Relat Dis. 2015;11(1):110–7.
66. Karlsson J, Taft C, Ryden A, et al. Ten-year trends in health-related quality of life after surgical and conventional treatment for severe obesity: the SOS intervention study. Int J Obes. 2007;31(8):1248–61.
67. Kolotkin RL, Davidson LE, Crosby RD, et al. Six-year changes in health-related quality of life in gastric bypass patients versus obese comparison groups. Surg Obes Relat Dis. 2012;8(5):625–33.
68. Nickel MK, Loew TH, Bachler E. Change in mental symptoms in extreme obesity patients after gastric banding, part II: six-year follow up. Int J Psychiatry Med. 2007;37(1):69–79.