Obesity and Common Surgical Disorders, Effects on Incidence and Complications

Doctoral Thesis

by

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To Christina
Abstract

**Background:** Overweight and obesity are becoming increasingly common, not only in the developed countries but also in developing countries. It is well documented that obesity increases the risk of several medical disorders; however, less is known of effects of obesity on common surgical disorders and treatments.

**Objectives:** To study overweight and obesity and their effects on the incidence of diverticular and groin hernia disease, type of surgery in general and groin hernia surgery in particular.

**Patients and databases:** The effect of overweight and obesity on diverticular disease, groin hernia disease and the incidence of surgery were studied prospectively in a cohort of 7,495 Swedish men from the Multifactor Primary Prevention Study. The men were examined at 47-55 years of age and followed for 28-38 years. Hospitalization with a discharge diagnosis of diverticular or groin hernia disease, as well as operation codes, was registered during follow-up. For groin hernia surgery, the Swedish Hernia Register was used. Obesity was defined as a body mass index (BMI) > 30 kg/m\(^2\).

**Results:** In the cohort 112 men (1.5 %) were hospitalized with diverticular disease during 28 years of follow-up. Hospitalization was significantly more common in overweight men (BMI 25 to 27.5 and 27.5 to 30 with hazard ratios (HR) 3.0 and 3.2 respectively) and in obese men (HR 4.4) than in men of normal weight (BMI 20 to 22.5). Totally, 1,017 men (13.6%) were hospitalized with groin hernia during 28 years of follow-up: Significantly fewer overweight men (BMI 27.5 to 30 kg/m\(^2\), HR 0.74) and men with obesity (HR 0.57) were hospitalized in comparison with men of normal weight. Investigation of 49,094 groin hernia operations in both men and women showed that surgery in women, femoral hernia and emergency operations were more common in underweight (BMI <20 kg/m\(^2\)) individuals than in the other BMI classes. Postoperative complications in groin hernia surgery were significantly more common in underweight (HR 1.27), overweight (HR 1.10) and obese (HR 1.62) patients as compared with patients with normal weight. Altogether, 13,210 operations were performed in 7,495 men during 38 years of follow-up. No difference in BMI was found between middle-aged men with or without subsequent surgery. By contrast, increasing BMI reduced the risk of pulmonary surgery (HR 0.91), compared with a BMI <20 kg/m\(^2\).

**Conclusions:** Hospital admissions due to diverticular disease increase with increasing BMI. In contrast, obesity reduces the risk for inguinal hernia surgery. The proportions of hernia repair in lean patients are greater for women, femoral hernia and emergency admission than in normal and overweight persons. Finally, in Swedish men BMI at the age of 47-55 does not predict the risk of future surgical intervention during an extended follow-up.

**Key words:** Obesity, BMI, diverticular disease, groin hernia, postoperative complications, groin hernia repair, surgery, incidence, complications
List of publications

This thesis is based on the following publications and manuscript, which are referred to in the text by their Roman numerals (I-IV).


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Abbreviations

BMI  body mass index
CHD  coronary heart disease
IAP  intra-abdominal pressure
HR   hazard ratio
WHR  waist to hip ratio
WC   waist circumference
PIN  personal identification number
ICD  International Classification of Diseases
NPR  National Patient Register
ASA  American Society of Anesthesiologists Physical Status
     Classification System
IASO International Association for the Study of Obesity
CI   confidence interval
MCF  Mean Cumulative Function
Introduction

Almost 750,000 operations are performed in Sweden (about 10,000/100,000 individuals and year) every year and many more people are affected by surgical disorders [1] [2]. The proportion of obesity, defined as a body mass index (BMI) of more than 30 kg/m², in the Swedish population has been found to increase in both older as well as younger persons. Alarmingly the prevalence of obesity today is between 10 and 20 % [3]. The correlation between medical disorders (such as coronary heart disease, stroke and other cerebrovascular diseases as well as type 2 diabetes) and obesity is well defined [4-7]. Obesity is associated with a number of complications including increased risk of postoperative wound infections, and complications during/after anesthesia such as venous thrombosis and respiratory impairment [6, 8-11]. However, little is known about the relation between obesity and specific surgical disorders. Since many people are affected by and treated for surgical disorders, and an increasing number are affected by obesity, it is relevant for future medical management to study how obesity affects surgical disorders. Obesity could affect both the incidence of surgical disorders and the outcome of surgical treatment. The aim of this thesis is to increase our knowledge about the effect of obesity on surgical disorders.
Background

Obesity

Fat deposits are the way the human body stores energy. Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health [12]. An increased intake of energy-dense foods that is high in fat and sugars and decreased physical activity due to the increasingly sedentary nature of many forms of work, changing modes of transportation and increasing urbanization are known factors associated with obesity [12]. Although Hippocrates (460-370 BC) regarded obesity as not only a disease per se but also the harbinger of other diseases, it was not until the mid-1900s that obesity was first associated with increased mortality, based on tables of “ideal” weights statistics from life insurance companies [13, 14] [15, 16]. Since the 1950s, obesity is considered a serious disease. Today, it affects a growing number of people in both developed and developing countries [17].

Obesity definition

The reason for the classification of overweight and obesity is to identify individuals and groups who are at increased risk of illness and death caused by overweight and obesity. Obesity, overweight, normal weight and underweight are most commonly classified using BMI. For adults it is defined as weight in kilograms divided by the square of height in meters. The WHO has concluded that the lowest mortality and co-morbidity are associated with a BMI between 18.5 and 25 kg/m², which is defined as normal [18]. Obesity is defined by the WHO as a BMI >30 kg/m². BMI above 30 kg/m² does not always imply obesity [19]. The relative tissue density is higher for muscle tissue than for fat. Muscular people can have a BMI > 30 kg/m² without being obese. Consequently, over-diagnosis of obesity with corresponding underestimation of BMI as a risk factor may occur. However, a BMI >30 kg/m² in a normal middle-aged population confirms obesity [20] [21]. In terms of age BMI increases up to 60-65 years but after that muscle mass decreases with concomitant changes
of about two BMI units until age 87 years [22]. Another study demonstrated the prevalence of obesity in different age groups [15]. Another way to measure obesity and assess risk is to measure waist circumference in proportion to hip circumference (waist-to-hip ratio, =WHR) or only waist circumference (WC). WC is sometimes a better predictor of disease than BMI (e.g. in predicting type 2 diabetes) [7]. However, there are other more sophisticated methods, to measure body fat including body composition methods (4-compartment model of body composition, 4C) and dual-energy X-ray absorptiometry (DXA) [23]. BMI, however is a simple index of weight-for-height that is commonly used in adults as a marker of health risk. It provides the most useful population level measure of obesity and can be used to estimate the prevalence of obesity within a population and the risks associated with it [24, 25].

Etiology and pathogenesis

Weight stability depends on a very precise autonomous regulation of the energy balance. If this balance were disturbed by environmental conditions such as would be the case of unlimited food or a sedentary lifestyle, risk for obesity increases [26]. Genetic factors are known factors that influence which individual are likely to gain weight and the magnitude of weight gain, as shown by overfeeding studies in twins [27]. Other risk factors are repeated pregnancies and various drugs [15, 28].

Epidemiology

The percentage of people with obesity has increased dramatically in most parts of the world but it is still relatively rare in Africa and Asia [29] [17]. In the USA from 30-40% of the population are affected by obesity; in Sweden, the corresponding figure is lower (10-20%) [30, 31]. During the years 1963-1993, the proportion of 50-year-old men in Gothenburg, Sweden, who were obese, increased from 6 to 11% [32]. According to Berg et al, the proportion of obesity in Gothenburg, Sweden was 11% for women and 15% for men in 2002 [33].
Education, work, living area, economics and, as mentioned earlier, genetic factors all influences obesity [34]. The BMI levels in the young people will probably continue to increase in the near future [35, 36].

Medical disorders

The relative risk of type 2 diabetes in obese individuals compared with individuals with normal weight was found to increase in men and women in a comprehensive review of the literature of the International Association for the Study of Obesity (IASO), a prospective cohort study and a large meta-analysis [4] [6, 7]. In addition, results from IASO and two meta-analyses showed that the relative risk for coronary heart disease (CHD) was increased in obese men and women according to results from IASO, and two meta-analyses [4] [5] [6]. Finally in a comprehensive review of IASO and in a large meta-analysis the risk for stroke increased in men and women with obesity [4] [6]. Obesity has also been shown to be associated with an increased risk of heart failure, asthma and pulmonary embolism [6, 37]. Concerning mortality and medical disorders BMI more than 25 kg/m² is a strong predictor for increased mortality in type 2 diabetes, ischemic heart disease and stroke [38].

Surgical disorders

Cancer

In the case of malignant diseases a large meta-analysis has shown that the incidence of cancer (kidney, colorectal, ovarian, uterine /endometrial, and postmenopausal breast cancer), with the exception of esophageal squamous cell cancer and prostate cancer, is associated with obesity [6]. However, esophageal adenocarcinoma in persons with obesity was more common than in normal-weight persons [39].
Colorectal cancer has also been associated with obesity, particularly colon cancer in both women and men and rectal cancer in men [40, 41] [6]. Prostate cancer was weakly associated with increased body weight, particularly in advanced stage tumors in obese individuals [6, 41, 42]. Breast cancer in post-menopausal women was weakly correlated with increasing BMI whereas tumors in premenopausal women showed a very weak inverse correlation with BMI [41] [6].

In a large cohort study of BMI and mortality from cancer in men from the USA, mortality was increased in obesity compared with normal weight for both death from all cancers combined and in all types except lung cancer. In lung cancer an inverse association with BMI and mortality was observed. For brain and bladder cancer, no significant associations were found. The results in women were similar [43].

Other disease

Obesity markedly increases the risk of benign prostatic hyperplasia [44] [45]. An increased risk of complications in diverticular disease, has been documented in obese individuals [46]. Gallstones are more common in obesity, particularly in women [47, 48]. Obesity also increases the risk of cholecystitis [49] [6]. Osteoarthritis, the most common joint disorder, occurs with increased frequency in the obese [50, 51] [52, 53] [6]. However, it is not clear whether osteoarthritis is caused by increased joint loading, a biochemical process, or both [54, 55].
The “obesity paradox”-decreased morbidity in obese people

Remarkably, there are exceptions to the established consensus that obesity is associated with disease and mortality. These exceptions have been called obesity paradoxes and are defined as better outcomes and reduced incidence in certain disorders in overweight and obese patients. Examples of this include the occurrence of primary groin hernia and traumatic hip fractures [56, 57]. Recent studies among critically ill patients in intensive care units or patients with acute heart failure have reported better outcomes in these overweight or obese patients than in normal weight patients [58, 59]. Mullen et al studied a large cohort of more than 100,000 patients undergoing non-bariatric surgery [60]. Overweight and obese patients demonstrated decreased mortality compared with patients of normal weight [60].
Diverticular disease

Incidence and prevalence

Diverticular disease is common and its prevalence increases with age [61-63]. It is characterized by protrusions of colonic mucosa through weakening in the colonic wall [64, 65]. Diverticular disease is more common among women [66]. Most patients are asymptomatic. The complications vary in severity, such as diverticulitis, perforation, abscess, stricture, fistula or bleeding [64]. In Gothenburg, the incidence of hospitalization for diverticulitis was 40/100,000 inhabitants annually and the incidence of perforated diverticulitis 4/100,000 in 2003-2008 [67]. In the past 20 years in Finland, the incidence of perforated diverticulitis has increased 50% to 3.8/100,000 inhabitants in 2000 [68]. The lifetime risk of suffering from diverticulitis has been estimated to be from 10-25% with an annual risk of 2% [64].

Etiology and pathogenesis

The cause of diverticular disease is unclear though age and lifestyle are important factors [61-63]. Diet has long been considered a major factor in the development of diverticular disease [64]. A diet deficient in fiber is suspected to cause diverticular disease by increased pressure in the intestine because of less gut content and longer transit time [64]. The argument of fiber deficiency and high pressure in the colon has been questioned because of the difficulties to measure and document pressure in the colon under physiological conditions.

Overweight, obesity and diverticular disease

Increasing BMI may correlate with the risk for diverticular disease complications [69-72]. Diet, especially a diet low in fiber is often associated with overweight and obesity [73, 74]. Another major cause of obesity is physical inactivity, which also has been shown to increase the risk for diverticular disease and concomitant complications [69, 75]. In conclusion, several studies have indicated
that lifestyle (i.e. diet and physical activity) and age are important determinants in the pathogenesis of diverticular disease of the colon.

**Groin hernia disease**

*Incidence and prevalence*

The incidence of inguinal hernia surgery in Sweden is approximately 200/100,000 inhabitants and year [76]. The prevalence of inguinal hernia is unclear but one study by Abramson et al has shown that men aged 65-74 years have an overall lifetime prevalence (including successful repairs) of obvious hernias of 31% and if subclinical hernia is included, the risk increases to 40% [77]. Other studies support these results [56, 78]. Inguinal hernia is 10 times more common in men than in women [79].

*Etiology and pathogenesis*

Groin hernia can be divided into inguinal hernia and femoral hernia. Femoral hernia surgery is 20 times more common in women than in men [79]. Inguinal hernia can be divided into indirect (lateral) and direct (medial). The etiology and pathogenesis are supposed to be combination of elevated intra-abdominal pressure (IAP) and a weakening of the abdominal wall [80]. Upright body position, coughing, physical labor and straining are all known to increase IAP. However, no studies have examined whether increased IAP results in primary inguinal hernia. To prevent inguinal hernias there is a mechanism where the muscles, fascia and aponeuroses cover the potential internal openings when IAP increases [81]. When this mechanism is not functional, concomitant with reduced strength in the muscle, aponeurosis or fascia, a hernia may occur. The incidence increases with age in parallel with the deterioration of tissue quality [82, 83]. Poorer tissue quality, which has been found in smokers, was associated with recurrent hernia [84]. Lateral inguinal hernia is most common, occurring in all ages. It is
considered not only congenital but also multifactorial in origin [85]. Medial hernia is acquired and is common in patients with connective tissue diseases [85]. There could, potentially, be a hereditary risk factor for the occurrence of both types of inguinal hernia [80].

**Overweight, obesity and inguinal hernia**

Obesity may be a risk factor for hernia development since overweight and obesity have been shown to result in an increased IAP [86, 87]. However, several studies suggest that overweight and obesity could prevent the occurrence of groin hernia [56, 77][88]. A hypothesis is that the abdominal wall muscles would be stronger through the weight of the excess fat and thereby provide a stronger barrier [56]. Accordingly, obesity may give rise to increased IAP but, paradoxically, also providing less risk of groin hernia.

**Frequency of surgical procedures in society**

In Sweden 750,000 operations requiring hospitalization are performed annually, which can also be expressed as 9,530 procedures per 100,000 individuals in 2009 [1] [2]. Further, several hundred thousand of procedures are performed as day surgery each year. One in 10 of the Swedish adult population undergoes a surgical procedure annually. One of three hospital beds are within surgical specialties [76]. Body weight -- high or low -- is known to affect the incidence of several diseases. High body mass is associated with increased risk for cardiovascular diseases [5, 6], cancers [6, 41, 89] [39], osteoarthritis [50-53], gallstones and benign prostatic hypertrophy [47-49] [44, 45], whereas low body mass is associated with increased incidence of hip fractures and inguinal hernias [56, 57]. To our knowledge, no study has investigated the effect of body mass on the prevalence of surgical operations. A limited number of studies have compared the prevalence of surgery in different geographical areas [2, 90, 91]. The knowledge of how many operations it is generally likely to undergo during life is
poorly known. Different factors, mainly a combination of funding and access to surgeons and hospital beds influence the prevalence of operations. However, no studies are available of the spectrum of operations occurring in a cohort of individuals examined at a specific time point and thereafter followed for several decades. Nor has the effect of weight (as measured by BMI) been studied in connection with disorders subject to surgical treatment.
Databases

Personal Identification Number (PIN)

Every Swedish inhabitant has a unique person identification number (PIN) that is universally used in official contexts. The PIN makes follow-up possible through cross-linkages between different databases and registers.

Multifactor Primary Prevention Study

The Multifactor Primary Prevention Study was initiated in 1970 [92]. The objective was to use various interventions to prevent CHD and stroke as well as to reduce mortality. The interventions were directed against smoking, hypercholesterolemia and hypertension. The population consisted of 30,000 middle-aged men born in Gothenburg from 1915-1922 and 1924-1925, who were divided into three randomly selected groups. Those born in 1923 were excluded since that cohort was already included in another long-term follow-up study in the city. Only men were selected for the study of their higher incidence of CHD. The study group was made up of 7,495 individuals (9,998 were initially randomized to the study group but 2,503 did not take part in the initial investigation). The two other groups were control groups of 10,000 men each. The first screening took place in 1970-1973. Information about smoking habits, physical activity during leisure time and diabetes mellitus was collected via a postal questionnaire. Weight was measured in kilograms to the nearest 0.1 kg; height was measured in meters to the nearest 0.01 m; and blood pressure was measured to the nearest 2 mmHg after 5 minutes rest with the participant seated. Serum cholesterol concentration (from a sample taken after fasting for at least 2 hours) was determined according to standard laboratory procedures [93]. Physical activity during leisure time was categorized into three levels of activity: sedentary, moderate activity (e.g. walking or light gardening for at least 4 hours per week), and regular, strenuous, or very strenuous activity for at least 2 to 3 hours per week. Smoking was classified into current and noncurrent smokers in studies I and IV and into four categories in study II: never smoked, former smoker for at least a 1-
month duration, smoking 1 to 14 g of tobacco per day, and smoking more than 15 g of tobacco per day. One cigarette was considered to contain 1 g of tobacco, 1 cigarillo 2 g, and 1 cigar 5 g. Interventions were offered those who fulfilled predetermined criteria. Ten years after entry, a 20% random subsample of both the intervention group and one of the two control groups were re-examined [94]. Serum cholesterol, smoking and blood pressure had decreased in both groups but there were no differences between the groups. The same changes must have taken place both in the men in the intervention group and in the men in the general population. Moreover, there were no differences in outcome regarding cardiovascular disease, cancer or all-cause mortality between the intervention and any of the control groups. Hence, the present study group was considered representative of the background population in the city. Data of mortality, cause-specific morbidity and operations were obtained from three sources: hospital files, the National Patient Register and the Cause of Death Register.

**The Swedish hernia register (SHR)**

The SHR started in 1992 and is a national quality register of hernia surgery [79]. It contains detailed information of every inguinal hernia or femoral hernia surgery in patients aged 15 years or older, i.e. of more than 150,000 surgical operations. Variables recorded according to a standardized protocol include age, gender, hernia anatomy, mode of admission, method of repair, postoperative complications, 30-day mortality, and reoperation for recurrence. Clinical follow-up is not mandatory, but any complication observed within 30 days after surgery has to be recorded in the database. The register is continuously being validated. The PIN makes follow-up possible through cross-linkages with the SHR and through record linkages to The Swedish Cause of Death Register and the National Patient Register.
The National Patient Register

In the 1960s, the Swedish National Board of Health and Welfare started to collect information regarding in-patients at public hospitals (the National Patient Register, NPR). Except for 1976 (because of a legislative change for that single year), data from the county council of Gothenburg have been registered since 1970. From 1987, the NPR includes all in-patient care in Sweden. The patient’s PIN, age, sex, date of discharge and medical data (diagnosis and procedures) are available in the NPR. Diagnoses have been registered with the Swedish classification that is based on The International Statistical Classification of Diseases, Injuries, and Causes of Death (ICD8 1969-1986, ICD9 1987-1996 and ICD10 1997-). Procedures are classified according to the Classification of Operations (used until 1996) and the Classification of Surgical Procedures (used from 1997) (Swedish version of NOMESCO Classification of Surgical Procedures Version 1.9). Information to the NPR is delivered to the Center for Epidemiology at the National Board of Health and Welfare from each of the 21 county councils in Sweden. At present, the NPR is updated once a year. The dropout rate for 2007 has been estimated to less than 1%. A quality control of the NPR is performed, which includes, for example, that compulsory variables (such as personal registration number, hospital stay and main diagnosis) are reported. Furthermore, the validity of all the values of the variables is tested [95]. If the data are obviously incorrect, correction is made. Finally, the corrected information is sent back to the liable unit for approval. The PIN makes it possible to follow each individual over time and the dropouts of PIN are close to zero (0.6% in 2006). In 2006, the main diagnosis was missing in 1.0%. The register has been evaluated for validity and completeness, and the codes for the main diagnoses were correct at the three-digit level for 92–94% of the records on surgical patients [96]. For surgical procedures (excluding endoscopies and biopsies), the codes were incorrect for 2% of the records and were missing for 5.3%.
The Cause of Death Register

The Cause of Death Register includes all persons who died during one calendar year and were registered in Sweden at the time of death [97]. The register, which is updated annually, contains cause of death data from 1961. Diagnoses have been registered according to The International Statistical Classification of Diseases, Injuries and Causes of Death (ICD8 1969-1986, ICD9 1987-1996 and ICD10 1997-). The dropout rate is under 1%. The Swedish Board of Health and Welfare is responsible for the register.
Aims

- to determine whether overweight and obesity in mid-life predict future hospitalization that is due to diverticular disease

- to establish whether overweight and obesity in mid-life predict future hospitalization that is due to groin hernia

- to analyze the effect of underweight, overweight, and obesity in relation to clinical characteristics (i.e. gender, age, hernia anatomy and mode of admission), the risk of postoperative complications, 30-day mortality, and reoperations for recurrence after groin hernia surgery

- to investigate whether body weight, as measured by BMI, in middle age predicts the need for future surgery
Patient and methods

Studies I, II and IV

Based on The multifactor Primary Prevention Study cohort of 7,495 men, discharges were identified by their PIN and cross-linkage with the National Patient Register and the Cause of Death register. For study I, those with discharge or death with a primary or secondary diagnosis code of diverticular disease according to ICD 8-10 were identified. For study II, patients with a discharge or death with a primary or secondary diagnosis code of groin hernia disease according to ICD 8-10 were identified. Finally, for study IV patients with a code of operation according to the Classification of Operations (used until 1996) and the Classification of Surgical Procedures (used from 1997-) in the National Patient Register were identified. Operations on the eye, ear and mouth and diagnostic procedures were excluded.

Study III

In the SHR 49,094 men and women with complete information on weight and height were identified from the period 2003-2007. Variables studied included age, gender, hernia anatomy, mode of admission, method of repair, American Society of Anesthesiologists Physical Status Classification System (ASA), postoperative complication, 30-day mortality and reoperation for recurrence of groin hernia. Postoperative complications were defined as hematoma, wound infection, urinary retention, severe pain, other (hernia recurrence excluded) and reoperation that was due to bleeding, hematoma, infection, severe pain, or intestinal obstruction within 30 days post-surgery. ASA is a classification system used to assess the degree of a patient’s "sickness”. An ASA 1 refers to a normal healthy patient and ASA 5 a moribund patient. Obesity is assessed as ASA 2 or 3 (morbid obesity=severe systemic disease) [98].
Statistics

Studies I and II

Prospective analyses were performed using Cox proportional-hazards regression models to identify factors related to a hospital discharge diagnosis of diverticular disease or groin hernia disease [99]. Time at risk was calculated to first hospitalization with a diagnosis of diverticular disease, to death, or to December 31, 1998. Time at risk for a diagnosis of groin hernia disease was calculated to first hospitalization, to death, or to December 31, 2004. To measure the relationship between BMI and diverticular disease or groin hernia disease BMI was entered into separate regression models, both as a continuous and as a categorical variable. Increasing levels of BMI were created by using six BMI categories: <20, 20 to 22.5, 22.5 to 25, 25 to 27.5, 27.5 to 30, and > 30 kg/m². Univariate regression analyses were used to evaluate potential confounders of the BMI-diverticular disease or groin hernia disease relationship. These potential confounders included systolic and diastolic blood pressure, serum cholesterol, smoking, sedentary leisure time and diabetes for diverticular disease or systolic and diastolic blood pressure, serum cholesterol, smoking, physical activity and diabetes for groin hernia disease. Variables were kept in the final multivariate regression models only if they met the criteria of P<0.15. We checked the assumption of proportional hazards by entering in the Cox regression model time-dependent variables related to the factors we studied. The impact of these variables was not significant on the model fit, indicating that the assumption holds. The final regression model included age, BMI, smoking, and diastolic blood pressure for diverticular disease and age, BMI, smoking, and serum cholesterol for groin hernia disease.

Study III

The chi-square test was used in the study III to examine differences in the underlying distribution of hernia anatomy, emergency operation and occurrence of reoperation in groups with different BMI cut-off points. HR of postoperative complication or reoperation were
estimated by the Cox proportional-hazards regression model and given with 95% confidence intervals (CI) and P-values, where P <0.05 was considered significant.

**Study IV**

To assess the relationship between the rate of operations in various organs and body mass a Cox regression model for each organ while controlling for age and smoking was fitted. To correct for the bias due to the dependence between recurrent events, the robust variance estimator for Cox regression was used [100]. In addition the mean cumulative function (MCF) of operations is presented in graphs for different combinations of covariate values. Briefly, the MCF is defined as follows: At time $t$, the participants have a distribution of their cumulative number of operations. The distribution of these values for each time point has a mean value called MCF. After the analysis, HR and 95% CI were obtained. P-values <0.05 were considered significant.

All statistics, particularly multivariate analyses were performed with the assistance of statistical experts.

**Ethics**

All participants gave their informed consent before inclusion in the studies and all procedures were approved by the Research Ethics Committees at Gothenburg or Umeå University.
Results

Study I

In this study of 7,495 men from the Multifactor Primary Prevention Study, our aim was to examine whether overweight and obesity in mid-life predict future diverticular disease. During 28 years of follow-up 112 of 7.495 (1.5%) men were hospitalized due to diverticular disease. The most common complications to diverticular disease were diverticulitis (42.9%), perforation (14.3%) and diverticular bleeding (14.3%). Other less common complications were obstruction, fistulae, diverticulosis, painful diverticular disease and abscess. The mean age at diagnosis was 67 years.

For middle-aged men (47-55 years) with a BMI of 25 to 27.5 kg/m$^2$, the risk was 3.0 times greater than for men in the reference group (BMI 20 to 22.5 kg/m$^2$) to be hospitalized due to diverticular disease. The risk increased to 3.2 times in men with a BMI of 27.5 -30 kg/m$^2$ at inclusion. For men with a BMI >30 kg/m$^2$ at inclusion, the risk to be hospitalized due to diverticular disease was 4.4 times higher than for those in the reference group as demonstrated in Table 1.

Table 1. Diverticular disease during the 28-year follow-up in multivariate analysis

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Multiple-adjusted HR (95 percent CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>3.0 (0.7-12.5)</td>
<td></td>
</tr>
<tr>
<td>20-22.5</td>
<td>1.0 (Referent)</td>
<td>-</td>
</tr>
<tr>
<td>22.5-25</td>
<td>2.3 (0.9-6)</td>
<td></td>
</tr>
<tr>
<td>25-27.5</td>
<td>3.0 (1.2-7.6)</td>
<td></td>
</tr>
<tr>
<td>27.5-30</td>
<td>3.2 (1.2-8.6)</td>
<td></td>
</tr>
<tr>
<td>&gt;30</td>
<td>4.4 (1.6-12.3)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Adjusted for age, smoking, diastolic blood pressure.
Study II

In this study of 7,495 men from the Multifactor Primary Prevention Study, our aim was to examine whether overweight and obesity in mid-life predict future groin hernia.

Of 7,483 men 1,017 (12 men were diagnosed before inclusion and excluded from the 7,495 sample) (13.6%) were hospitalized with groin hernia during the follow-up period of 34 years. The average age at diagnosis was 66 years. During the hospital stay, 90% of the men with a diagnosis of groin hernia underwent groin hernia surgery, as an elective admission though, some were admitted as an emergency with or without being operated.

Men with BMI > 30 kg/m² had almost half (HR 0.57) as many admissions for inguinal hernia disease as men with normal weight (i.e. a BMI of 20 to 22.5 kg/m²). Men with a BMI from 27.5 to 30 kg/m² had 0.74 (HR) as many hospitalizations compared with men of normal weight (i.e. BMI 20 to 22.5 kg/m²) as shown in Table 2.

### Table 2. Groin hernia disease during the 34-year follow-up in multivariate analysis

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Multiple-adjusted HR (95 percent CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age(yr)</td>
<td>1.05 (1.02-1.08)</td>
<td>0.0003</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>0.83 (0.53-1.29)</td>
<td>0.40</td>
</tr>
<tr>
<td>20-22.5</td>
<td>1.00 (Referent)</td>
<td>-</td>
</tr>
<tr>
<td>22.5-25</td>
<td>1.03 (0.85-1.26)</td>
<td>0.76</td>
</tr>
<tr>
<td>25-27.5</td>
<td>1.02(0.83-1.25)</td>
<td>0.86</td>
</tr>
<tr>
<td>27.5-30</td>
<td>0.74 (0.58-0.94)</td>
<td>0.013</td>
</tr>
<tr>
<td>&gt;30</td>
<td>0.57 (0.41-0.79)</td>
<td>0.0009</td>
</tr>
</tbody>
</table>

Adjusted for age, smoking, serum cholesterol
Study III

The aim of study III was to examine the effect of underweight, overweight and obesity in relation to clinical characteristics (age, gender, hernia anatomy, mode of admission and method of repair), the risk of postoperative complications, 30-day mortality, and reoperations for recurrence after groin hernia surgery in the SHR. Between January 1, 2003 and December 31, 2007, 75,116 primary groin hernia operations were registered in the SHR. Of these, 26,022 were excluded because of missing data on weight or height, leaving 49,094 primary hernia operations for analysis. In general, differences between patients included in the study and those excluded were relatively small; however, missing data were more common for emergency procedures, femoral hernias and older patients. The proportion of obesity was 5.2%. The distribution in BMI groups, together with gender, hernia anatomy and mode of admission is illustrated in Table 3.
Of the 49,094 persons who underwent surgery, 3,760 (7.7%) were women. In contrast the percent of women in the underweight operated group (BMI <20 kg/m²) was 30%. In the group with a BMI <20 kg/m² the percentage of femoral hernias in the group of hernia anatomy (i.e. lateral, medial and combined hernia) was 9.7 %, i.e. four times larger than in the other BMI groups. Further, this pattern was more common in women than in men, especially in underweight women. In comparison with the other BMI groups, emergency surgery was 2.5 times higher in men and women with a BMI <20 kg/m² (7.8 %). The proportion who underwent emergency surgery was at least twice as large in women than in men in all BMI groups. The postoperative complication rate, and reoperation due to complications within 30 days post-surgery was lowest in normal-weight individuals and higher.
among those with a BMI <20 kg/m² or > 25 kg/m² as illustrated in Table 4.

### Table 4. Hazard Ratios for Postoperative Complication Versus BMI Independent of Surgical Techniques

<table>
<thead>
<tr>
<th>BMI kg/m²</th>
<th>Hazard Ratios</th>
<th>95% Confidence Interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>1.27</td>
<td>1.07-1.50</td>
<td>0.005</td>
</tr>
<tr>
<td>20-25</td>
<td>1(Ref)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-30</td>
<td>1.10</td>
<td>1.03-1.18</td>
<td>0.005</td>
</tr>
<tr>
<td>&gt;30</td>
<td>1.62</td>
<td>1.42-1.85</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Adjusted for Gender, Age, and Emergency Admission

Study III showed more ASA 3 and 4 in underweight persons. Table 5 illustrates that reoperation for recurrence in overweight persons was higher than in persons with normal weight.

### Table 5. Hazard Ratios for Reoperation Versus BMI Independent of Surgical Techniques

<table>
<thead>
<tr>
<th>BMI kg/m²</th>
<th>Hazard Ratios</th>
<th>95% Confidence Interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>1.06</td>
<td>0.70-1.62</td>
<td>0.78</td>
</tr>
<tr>
<td>20-25</td>
<td>1(Ref)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-30</td>
<td>1.19</td>
<td>1.00-1.40</td>
<td>0.05</td>
</tr>
<tr>
<td>&gt;30</td>
<td>1.30</td>
<td>0.93-1.82</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Adjusted for Gender, Age, and Postoperative Complications

A subgroup analysis of different operative techniques showed that hernia repaired by the Lichtenstein technique gave the lowest relative risk for reoperation in all BMI groups. When BMI was taken into account, overweight and obese patients repaired with the open suture or open preperitoneal techniques had increased risk of 1.68 and 8.23 (vs. Lichenstein technique) respectively for reoperation for recurrence.
Study IV

Of 7,495 men who were included in the Multifactor Primary Prevention Study 1,810 (24%) died without having been registered for any surgery and 537 (7%) were still alive without having undergone surgery. The other 5,148 persons (69%) underwent 13,210 operations (an average of 2.6 operations per person) during 38 years of follow-up. Baseline risk factors are illustrated in Table 6.

Table 6. Baseline Risk Factors by the presence or absence of Surgery at Follow-Up

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Surgery (n=5,148, 68.7%)</th>
<th>No surgery (n=2,347, 31.3%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at baseline, yr, mean (SD)</td>
<td>51.56 (2.25)</td>
<td>51.59 (2.33)</td>
</tr>
<tr>
<td>Age at first operation, (yr), mean (SD)</td>
<td>65.64 (9.36)</td>
<td></td>
</tr>
<tr>
<td>Body Mass Index, mean (SD)</td>
<td>25.53 (3.17)</td>
<td>25.58 (3.47)</td>
</tr>
<tr>
<td>Number of current smokers (%)</td>
<td>2,456 (48)</td>
<td>1,228 (53)</td>
</tr>
<tr>
<td>Dead, number (%)</td>
<td>3,801 (73.8)</td>
<td>1,798 (76.6)</td>
</tr>
</tbody>
</table>

BMI was not associated with the likelihood of surgery during the extended follow-up in middle-aged men in this study. Mean BMI at inclusion in the surgery group was 25.53 versus 25.58 kg/m$^2$ in the non-surgery group as shown in Table 6.

After the subdivision of the surgery group into 10 groups of organ, groups of organs or organ systems as illustrated in Fig.1, gastrointestinal (28.6 percent), urogenital (25.3 percent), and orthopedic (20.1 percent) operations constituted 75% of all procedures.
There were significantly fewer men with higher BMI in patients with operations of the bronchi and lungs, with hazard decreasing (0.91-1, i.e. -9%) per BMI unit increase (95% CI, 0.87-0.96, P <0.0001) and marginally more men with higher BMI in those with operations of the musculoskeletal system. The hazard increases by (1.03-1, i.e. 3%), 95% CI,1.01-1.04, P=0.003, per BMI unit increase, independently of age and smoking.
Discussion

The risk of hospitalization for diverticular disease during follow-up was related to BMI in midlife, with increasing risk already from a slightly elevated BMI. The highest risk was observed in men who had the highest BMI. Our finding of a comparatively low incidence of hospitalizations is likely because only severe cases require hospital admission, whereas many mild diverticulitis episodes are treated at home. Indications that obesity might contribute to the incidence of complications and recurrent disease have been reported in two retrospective studies [70, 71]. However, in another retrospective small study no association between diverticular bleeding and obesity was found [101]. In a prospective study of 47,228 men followed for 18 years Strate et al. confirmed our results finding that increasing BMI leads to increased risk of diverticulitis and diverticular bleeding [46]. Although there are differences in study design with regard to complication registration and age distribution within the cohort, when BMI and complication data were registered both studies gave consistent results. However, if obesity contributes to the prevalence of asymptomatic diverticular disease, diverticulosis, is not known.

A low fiber diet has been postulated to cause diverticular disease. Low physical activity levels and high levels of sedentary behavior have been demonstrated in studies by Aldoori et al. and Strate et al. to be a risk for symptomatic diverticular disease [69, 75] [102]. Obesity is also associated with a low fiber diet and a sedentary lifestyle [74] [73]. These risk factors could be common denominators of both diverticular disease and obesity. Our study did not include dietary data in contrast to the study of Strate et al where there were, however, only modest associations with symptomatic diverticular disease. No correlation of low physical activity and hospitalization for diverticular disease was found in study I of the present thesis. An explication could be that the activity questionnaire, which was only divided into three levels, was not predictive of diverticular disease. In their article of obesity as risk factor for diverticular disease Strate at al., found only a modest association [46]. Complications of diverticular disease are mainly related to inflammation. Diverticular bleeding is an exception which is probably not associated with inflammation of the
colon but rather to changes in the vessels adjacent to the diverticula [101, 103]. Diverticulitis has been shown to be associated with increased risk of left-sided cancer of colon [104]. There is also an association between colorectal malignancy and obesity, as well as an association between obesity and inflammation [105]. Subclinical and clinical inflammation have been hypothesized to induce a pro-growth environment for malignant lesions [106]. This hypothesis of pro-growth environment and chronic obesity-induced low-level inflammation may contribute to the risk of developing inflammation of diverticular disease.

Study I was limited to middle-aged men who have a relatively homogeneous ethnic background. Accordingly, the results may not be applicable to women, to younger cohorts or to persons from other ethnic groups. However, diverticular disease is more common in the elderly.

Regarding groin hernia, a relationship was found between elevated BMI in middle-aged men and reduced incidence of groin hernia during follow up suggesting that increased higher BMI protects against groin hernia. That increased BMI protects against groin hernia has been indicated in previous studies. In 1970, for instance, Abramson showed in 1,883 men over the age of 25 years that overweight and obesity (i.e. a BMI > 28 kg/m²) was associated with fewer inguinal hernias [77]. Abramson’s study has been followed by a case-control study of 89 women that showed a BMI > 30 kg/m² decreased the risk of inguinal hernia [88]. In 2007, Ruhl et al. published a study of risk factors for inguinal hernia in 5,314 men [56]. The study participants were younger (age 24-74 years) and the follow-up period shorter (median 18.2 years) than in our study. The proportion of men with a diagnosis of inguinal hernia, was similar in study II (13.6%) and in the study of Ruhl et al. (13.9%) [56]. After multivariate regression, obese persons had a HR of 0.51 and those with overweight a HR of 0.79 [56]. There may be several reasons for the reduced hernia incidence in obesity. In the pathogenesis of inguinal hernia increased IAP has been
proposed to be a risk factor resulting in an imbalance between IAP and abdominal wall resistance. Since elevated BMI is thought to be associated with increased IAP, obesity may contribute to groin hernia [86]. De Luca et al. and Ruhl et al. demonstrated in patients with hiatal hernia an increased incidence of groin hernia, possibly explained by increased IAP [56, 107]. However, scientific evidence concerning the relationship between IAP and groin hernia is weak. Physical activity is also associated with an effect on IAP [86]. Neither our study, nor the studies by Ruhl et al. or Abramson have shown that physical activity was associated with inguinal hernia [56, 77]. However, two studies have shown that physical activity increased the risk of inguinal hernia and one in women that it reduced the risk [88, 108, 109]. Physical activity may result in stronger musculatures of the abdominal wall. The hypothesis of increased IAP with higher BMI and accompanying increased risk for groin hernia is not in accordance with the result of fewer inguinal hernias. The protective effect of overweight and obesity must work through a more powerful mechanism that first overcomes the risk associated with increased IAP and then serves as a protective factor. Preperitoneal fat, could bulge over the edge into the hernia opening and reduce the diameter or completely obliterate it. Furthermore, the mesentery and the omentum in individuals with visceral obesity may be shorter and thicker. This condition would prevent abdominal content to protrude through the hernia opening. It is not known whether obesity, even if the abdominal wall is thicker, is associated with higher strength to resist IAP. Another explanation could be that it is easier to make a diagnosis through inspection and palpation of inguinal hernia in lean than in obese patients. However, overweight and obese people are likely to have the same symptoms as lean people. Moreover, comorbidity in overweight and obese persons leads to more doctor contacts, with a concomitant increase in the chance of detecting a groin hernia. Subsequent studies of inguinal hernia surgery have shown that underweight persons, especially women, have a greater risk of being operated on than those with higher BMI. (III) Study II was limited to middle-aged men that have a relatively homogeneous ethnic background. Accordingly, the results may not be applicable to women, to younger cohorts or to persons from other ethnic groups. However, most of all groin hernias occur in older men.
Of 49,094 performed primary groin hernia surgeries registered in the SHR from 2003 to 2007, 3,760 operations (i.e. 7.7%) were on women. In contrast, 29% of the operations in those with a BMI <20 kg/m$^2$ were done on women. Femoral hernia and emergency surgery were also more common, 4 and 2.5 times respectively, in the underweight group than in the other groups. The proportion of women who had emergency surgery was larger than the proportion of men, regardless of BMI group. In general, men had higher BMI values than women, which can affect the proportion of men and women in the underweight group [22].

The finding that low BMI contributes to increased hernia surgery in women has not previously been reported. Recent studies concerning the association between overweight and obesity and primary groin hernia in women have produced conflicting results [56, 88]. A hospital-based case-control study of Dutch women showed that overweight was associated with a lower risk for groin hernia, whereas a prospective study, however, reported that the risk was unrelated to overweight and obesity [56, 88]. The general clinical experience is that hernia is common in lean women or women with recent weight loss. A mechanical reason for this could be that preperitoneal fat disappears from the hernia opening and ultimately causes herniation. Femoral hernia surgery was most common in patients with a BMI <20 kg/m$^2$ with a dominance of women which can be explained by the fact that femoral hernia is unusual in men.

Previously, in study II, the difficulty in diagnosing inguinal hernias in obese persons has been discussed. This could lead to a false conclusion that obesity would protect against primary inguinal hernia. The high prevalence of emergency hernia surgery in persons who are underweight showed that it is not always easier to make the diagnosis in lean persons. In a recent survey emergency hospital admission was the first indication of hernia in 15 of 24 patients presenting with incarcerated femoral hernia [110]. Previous studies have shown that women had a higher proportion of emergency hernia surgery than men (17% vs. 5%) to compare with our study (9.3 vs. 2.6 %) respectively [111]. Concerning emergency femoral hernia, more women (40.6%) than men (28.1%) underwent surgery [112]. Consequently, emergency operations in general and femoral hernia repair in particular are thus often performed in women. Some of them are
women who are underweight. It was demonstrated that postoperative complications (e.g. hematoma in men and infection in women) were more common in obese persons than in normal-weight persons. Increased risk for underweight and a trend to increased risk for postoperative complications in obese has previously been shown in a study of hernia repair in men by Lindstrom et al.\[113\]. The risk of complication may be of anesthetic, or a surgical/technical nature, or it may be due to an increased susceptibility to infections in underweight persons and obese persons [8, 9, 114-117]. The distribution of more individuals in ASA class 3-4 (severe systemic disease or worse) in underweight individuals could be explained by the fact that some systemic diseases result in weight loss.

Reoperations for recurrence were found to increase in persons who are overweight. Open suture and open preperitoneal mesh techniques in overweight and obese individuals were associated with more reoperations. It may be more technically difficult to perform operations in overweight and obese individuals particularly with these methods of repair.

The prevalence of obesity in the operated patients (5%) was low as compared with the currently reported rate of at least 10% in the Swedish population [118].

Concerning operations in general, on average 2.6 operations per individual were conducted, i.e. 13,210 operations were performed in the middle-aged cohort and during an extended follow-up. There was no difference in BMI between the two groups having or not having surgery, i.e. that BMI in mid-life was not predictive for future surgery. With a general outcome, such as the need for surgery from a lot of disorders and an exposure variable that could influence each of these disorders in different ways, this observation was not unexpected. After division of operations into 10 groups of organs according to the Classification of Operations, more men with low BMI were found among those with later surgery on the bronchi and lungs. In contrast high BMI in middle age predicted marginally more orthopedic procedures.

The most common diagnosis treated surgically for diseases of the
bronchi and lungs is cancer. A large systematic review and meta-analysis of prospective studies with respect to the diagnosis of cancer of the bronchi and lungs has shown that lung cancer is associated with lower body weight [41]. Cancer of the lungs is associated with smoking in 80-90% of cases. In some previous studies smoking has been associated with lower body weight [119, 120]. Smoking is a powerful confounder for lung cancer and could be an explanation of our results. Koh et al. found that the combination of low BMI and smoking increases the risk of lung cancer compared with the combination of high BMI and smoking [121].

Orthopedic surgery was marginally more common in obese persons in mid-life than underweight persons. Two common diagnoses in orthopedic surgery are traumatic hip fracture and osteoarthritis. For our population of 7,495 men, the risk of hip fracture decreased with increasing BMI [57]. For osteoarthritis, there are, however, studies suggesting a direct association with BMI [6, 50-53]. Higher BMI causes more surgery on the musculoskeletal system, although some studies indicate that it protects against hip fractures.

For all other groups of organ, BMI in midlife was not predictive of future surgery. BMI in middle age affects the prevalence of individual operations as part of the major groups. Studies have shown that cholecystectomies were more common among obese individuals than in the reference population, with a mean BMI of 25.8 kg/m² (5.7% vs. 1.0%) [49]. Surgery for inguinal hernia or hip fracture was lower in overweight and obese persons (II) [57]. BMI can still exist as a risk factor for specific conditions, as exemplified by cholecystectomy, groin hernia surgery and hip-fractures, even though it was not obvious in the large group. Study IV was limited to middle-aged men of a comparatively homogeneous ethnic background. Accordingly, the results may not be applicable to women, to younger cohorts, or to persons from other ethnic groups. No formal control was performed as to whether some operations were missed by the hospital discharge register.

Risk factors, diseases and particular surgical treatments are constantly changing and being refined. All these must be taken into account when drawing conclusions and applying them to the medical challenge of today.
Summary

This thesis examined how obesity, as measured by BMI, affects the incidence of two common surgical disorders: diverticular disease and groin hernia disease. Overweight and obesity were strongly linked to future severe diverticular disease leading to hospitalization. For groin hernia, however, overweight and obesity were associated with a lower risk for future hospitalization. When the first surgical procedure for groin hernia was studied in a large national quality register, a relative dominance of women, femoral hernia and emergency operations among the underweight (i.e. BMI <20 kg/m^2) was demonstrated. Both lean and obese patients have an increased risk of postoperative complications. Furthermore, the present thesis showed a markedly low prevalence of obesity among the patients in the SHR. Finally, the risk of middle-aged and older men developing medical conditions requiring surgery was studied in a large community-based cohort. The main finding was that BMI in middle age was not predictive of future surgery. However, when evaluating individual organs/organ systems, men with a lower BMI more often required surgery of the bronchi and lungs, whereas men with a higher BMI was associated with marginally more operations of the musculoskeletal system. Overweight and obesity as well as underweight have an effect on the incidence of common surgical disorders and postoperative complications.

Conclusions

The studies of this thesis show that the number of hospital admissions due to diverticular disease increases with increasing BMI and that obesity reduces the risk of hospital admissions due to inguinal hernia disease. Furthermore, the proportions of hernia repair in lean patients are greater for women, femoral hernia and emergency operations than in normal and overweight persons. Finally, BMI of Swedish men aged 47-55 years does not predict the risk of future surgical procedures during a 38 year follow-up.
Sammanfattning på svenska

Kirurgiska sjukdomar och operationer är vanliga. Andelen personer som utvecklar fetma ökar, inte bara i västvärlden utan i hela världen. Fetma ökar risken för att drabbas av vanliga intern-medicinska sjukdomar som hjärt- och kärlsjukdomar samt diabetes. Om hur fetma påverkar vanliga kirurgiska sjukdomar som divertikel- och ljumskbråcks-sjukdomen samt operationer är kunskapen avsevärt lägre. Målsättningen med denna doktorsavhandling var att undersöka om:

- övervikt och fetma i medelåldern påverkar risken för män att drabbas av komplikationer till divertikelsjukdom
- övervikt och fetma i medelåldern är en risk för att drabbas av framtida ljumskbråckssjukdom hos män
- kroppsvikten (mätt som BMI) är en riskfaktor för att behöva genomgå en operation för ljumskbråck samt om kroppsvikten påverkar risken för akuta operationer, komplikationer efter operationer, dödlighet och om-operationer för återfall av ljumskbråck efter operation
- övervikt och fetma i medelåldern är en risk för framtida operationer

Längd och vikt utgör grunden för kropps Vikts index (Body Mass Index, BMI) och är ett enkelt och välanvänt sätt att klassificera övervikt och fetma. BMI mellan 18,5-25 kg/m² är normalt, BMI mellan 25-30 är lika med övervikt och BMI mer än 30 är definitionsmässigt fetma.


Delarbete I visar att överviktiga och män med fetma i högre utsträckning än normalviktiga män drabbades av komplikationer till divertikelsjukdomen senare i livet vilka krävt inläggning på sjukhus. En orsak kan vara att fetma i sig leder till en låg-gradig inflammation som kan medföra att de med divertiklar lättare drabbas av komplikationer.


I delarbete III analyserades uppgifter om 49,094 svenska män och kvinnor som opererats för ljumskbråck. Analysen visade att kvinnor som opererades i hög utsträckning var underviktiga med BMI <20, att femorala bråck (lårbråck) var vanligare bland underviktiga och att underviktiga oftare drabbades av akuta ljumskbråcksooperationer än normalviktiga, överviktiga och de med fetma. Underviktiga och överviktiga män och kvinnor samt de med fetma hade fler komplikationer, t ex blödning eller infektion, efter operation för ljumskbråck än de med normal vikt.
I delarbete IV studerades operationer utförda inne-liggande på sjukhus (ej sk dagkirurgi). I Sverige utförs omkring 750,000 operationer av denna typ årligen. Med start 1970-73 och under de efterföljande 38 åren genomgick 5,148 av 7,495 (69%) män totalt 13,210 operationer. 25% av männen avled utan att ha genomgått någon operation. Analys av BMI i medelåldern visade att övervikt och fetma inte påverkade risken för att senare under livet genomgå ett operativt ingrepp. Om analysen delas upp på typ av operation och/eller organgrupper hade de som var underviktiga i medelåldern en större risk att genomgå lungoperationer och män med fetma en marginellt ökad risk att genomgå framtida operationer pga ortopediska sjukdomar/skador i framtiden.

I korthet visade studierna att antalet inläggningar för divertikelsjukdom ökade vid övervikt och fetma och att fetma minskade risken för att bli inlagd på sjukhus på grund av ljumskbräckssjukdom. Underviktiga som opererades var oftare kvinnor, opererades oftare akut och opererades oftare för femoralbråck (lårbråck) än normalviktiga och överviktiga personer. Slutligen visades att kroppsvikten hos medelålders män inte hade betydelse för risken att behöva genomgå en operation senare under livet.
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Paper I-IV