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LOWER BODY CONTOURING SURGERY AFTER MASSIVE WEIGHT LOSS – PREVALENCE, OUTCOMES AND EFFECTS ON PREGNANCY AND DELIVERIES

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ACADEMIC DISSERTATION

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We dance round in a ring and suppose,
but the secret sits in the middle and knows.
-Robert Frost

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LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, referred to in the text by their Roman numerals:

I Pajula S, Jyränki J, Tukiainen E, Gissler M, Koljonen V. Actualised lower body contouring surgery after bariatric surgery – A nationwide register-based study. J Plast Surg Hand Surg. 2020 Aug 10:1–7.

II Pajula S, Gissler M, Kaijomaa M, Jyränki J, Tukiainen E, Koljonen V. Pregnancy and delivery after lower body contouring surgery is safe for the mother and child J Plast Reconstr Aesthet Surg. 2020 Aug 13: S1748–815.

III Pajula S, Jyränki J, Tukiainen E, Koljonen V. Complications after lower body contouring surgery due to massive weight loss unaffected by weight loss method. J Plast Reconstr Aesthet Surg. 2019 Apr 72(4):649–655.

IV Pajula S, Jyränki J, Caravitis L, Tukiainen E, Koljonen V. Muscle strength of massive weight loss patients admitted for lower body contouring surgery is low. Submitted.

These publications have been reprinted with the permission of their copyright holders. In addition, some unpublished material is presented.

ABBREVIATIONS

AGB	adjustable gastric banding
ASA	The American Society of Anaesthesiologists
BCS	body contouring surgery
BDD	body dysmorphic disorder
BMI	body mass index
BPD	biliopancreatic diversion
BS	bariatric surgery
DS	duodenal switch
GDM	gestational diabetes mellitus
JIP	jejunoileal bypass
LBCS	lower body contouring surgery
LRYGB	laparoscopy Roux-en-Y gastric bypass
LSG	laparoscopy sleeve gastrectomy
MDT	multidisciplinary team
MLOS	mean length of hospital stay
MWL	massive weight lost
NHDR	national hospital discharge register
PCOS	polycystic ovary syndrome
PE	pulmonary embolism
PIC	personal identity code
PRS	Pittsburgh rating scale
QoL	quality of life
RYGB	Roux-en-Y gastric bypass
SG	sleeve gastrectomy
SO	sarcopenic obesity
T2DM	type 2 diabetes mellitus
VTE	venous thromboembolism

ABSTRACT

Background. After significant weight loss due to surgical or non-surgical methods, the skin and soft tissue around the body do not normalise or become as tight as it was before weight change. The excess redundant skin can cause functional, physical, and physiological challenges, negatively affecting self-image and quality of life (QoL). Following bariatric procedures, an increasing number of patients are seeking body contouring surgery (BCS). BCS is the only effective treatment to remove redundant skin after massive weight loss (MWL).

Aims. Lower body contouring surgery (LBCS) was evaluated with respect to prevalence, outcomes, preceding muscle strength, and its effect on pregnancy and delivery in patients who had significant, redundant skin folds due to MWL.

Patients and Methods. This thesis comprises four original studies. First, cross-sectional comparison data from the Finnish Institute of Health and Welfare, the Hospital Discharge Register, the Medical Birth Register, Welfare and Statistics Finland, and the Causes-of-Death Registry were performed (Study I and II). There were altogether 7703 patients who received a bariatric procedure in Finland between 1998 and 2016 (Study I) and 92 fertile-age women who had undergone LBCS with or without preceding bariatric procedure and who experienced pregnancy and delivery afterwards between 1999 and 2016 (Study II). Secondly, a single-centre retrospective analysis study included 158 patients with MWL who had undergone LBCS between 2009 and 2015 (Study III). Finally, a prospective study including 23 patients with preceding MWL suitable for LBCS was recruited. Participants performed three muscle strength tests with age- and gender-related reference values before BCS. The muscle tests comprised hand grip strength, dynamic muscle strength of the body, and squat test (Study IV).

Main results. Altogether, 1089 (14.1%) of the 7703 bariatric patients underwent LBCS during the study period in Finland. Abdominoplasty was the most common lower body contouring procedure (89%). The median latency between bariatric surgery (BS) and LBCS was 31 months. Patients with LBCS were younger ($p<.001$) than those who had not undergone LBCS after BS. An annual correlation emerged between LBCS and bariatric procedures ($r=.683$). With a two-year latency between BS and LBCS, the correlation coefficient was high ($r=.927$). The number of LBCS ranged from 5 to 215 per hospital district in Finland. Most LBCS (97.3%) were performed in public hospitals (Study I).

In research data, of the 1 028 503 total pregnancies and deliveries in the study period, 92 women had had LBCS before pregnancy and delivery. These 92 women had planned Caesarean sections more often ($p <.001$), and pre-term delivery (<37 weeks) was more common among them ($p <.001$). Of the 92 women, 26 (28.3%) had a preceding bariatric procedure. Subgroup analysis

revealed that preceding bariatric procedures did not increase the risk for pre-term delivery or low birth weight. The need for urgent or emergency sections was not raised in the study group. None of the mothers or babies died (Study II).

A total of 96 complications occurred in 80 of the 158 patients, with an overall complication rate of 51%. Most complications (80.2%) were minor. Immediate complications (≤24 h) affected 8.3% of patients, early complications (1 to 7 days) 16.7%, late complications (7 to 30 days) 58.3%, and complications after 30 days 16.7%. In total, 57% lost weight through BS and 43% through lifestyle changes. No significant difference in complication rates existed between bariatric and non-bariatric patients. Older age (p=.042) at operation was associated with an increased risk for immediate haematoma or bleeding requiring surgery. Among early complications, a high maximum weight (p=.035) and a high pre-operative weight (p = 0.0053) significantly correlated with a haematoma or bleeding requiring surgery. For late complications, seroma correlated with older age (p =.0061) (Study III).

Study IV subjects comprised 18 women and five men, with a mean age of 48.2 years and 36.2 years, respectively. Of the participants, 17 (74%) had lost weight through BS and 6 (26%) through lifestyle changes. In the hand grip test, 60% had poor muscle strength. Likewise, 70% reached only the lower level in dynamic muscle strength of the body. The lowest squats performed in the squat test were ten and the highest 30 in 30 seconds.

Conclusions. The number of patients who undergo LBCS after bariatric surgery is relatively small in Finland. However, there is a strong correlation between bariatric surgery and two-year latency for LBCS.

The second study revealed that pregnancies after LBCS most often proceed to term. However, the risk for pre-term delivery and a low-birth-weight baby is increased, especially after prior bariatric surgery. There is also an increased risk of cesarean section, although probably due to other confounding factors. Longer latency between the contouring operation and pregnancy does not decrease the risks.

The complication rate after LBCS is relatively high, although most complications are primarily minor and non-life-threatening. No subgroup of MWL patients seemed to be more prone to complications. Thus, for each patient, the risks associated with LBCS following MWL should be considered individually.

Patients with preceding MWL have lower muscle strength than the age- and gender-matched average population. Especially the results of hand grip strength are considerably worse. This may indicate that patients suffer sarcopenia after MWL.

TIIVISTELMÄ (FINNISH ABSTRACT)

Taustaa

Merkittävän painon nousun seurauksena venyttyneet iho sekä pehmytkudokset eivät välttämättä palaudu alkuperäiseen muotoonsa massiivisen laihtumisen jälkeen, vaan jäävät roikkumaan haittaavina ihopoimuina erityisesti olkavarsien, rintojen, vatsan, kylkien ja sisäreisien alueille. Tyhjät ihopoimut voivat aiheuttaa toiminnallisia, terveydellisiä, psyykkisiä sekä esteettisiä ongelmia. Erilaiset paikalliset ihon paranemisongelmat, ihon hautuminen, bakteeri- ja sieni-infektiot sekä hygienian ylläpidon vaikeutuminen ovat yleisiä terveydellisiä ihopoimujen aiheuttamia ongelmia. Huolimatta massiivisen laihtumisen seurauksena parantuneesta yleisestä terveydentilasta saattaa elämänlaatu laskea merkittävästi roikkuvien ihopoimujen aiheuttamien vaivojen vuoksi. Suurin osa massiivisesti laihtuneista henkilöistä kärsii jossain määrin venyttäneestä ihoylimäärästä. Liikunta tai ruokavalio ei yleensä vaikuta merkittävässä määrässä venyttyneeseen kudokseen.

Vartalonmuokkauskirurgia on ainoa tehokas hoitomuoto laihtumisen jälkeisen ihoylimäärän poistoon, jossa palautetaan venyttyneen alueen anatomia. On tutkittu, että suurin osa potilaista, jotka kärsivät massiivisen laihtumisen seurauksena jääneistä tyhjistä ihopoimuista toivovat jonkinasteista vartalonmuokkaustoimenpidettä, mutta vain pieni osa todellisuudessa hakeutuu leikkaukseen.

Tutkimuksen tarkoitus

Tämän väitöskirjatyön tarkoituksena oli tutkia massiivien laihtumisen jälkeen tehtyjen alavartalonmuokkausleikkausten yleisyyttä, saatavuutta sekä alueellisia eroja Suomessa. Tämän lisäksi tutkittiin alavartalonmuokkausleikkauksen jälkeisiä komplikaatioiden esiintyvyyttä ja yleisyyttä massiivisesti laihtuneilla potilailla sekä selvitettiin aiemmin tehdyn alavartalonmuokkausleikkauksen vaikutusta raskauteen ja synnytykseen. Väitöskirjatyössä selvitettiin myös vartalonmuokkauskirurgialeikkaukseen hyväksyttyjen potilaiden lihaskuntoa ennen leikkausta.

Tulokset

Ainoastaan 14.1 % (1089) lihavuusleikatuista (7703) potilaista kävi alavartalonmuokkaustoimenpiteessä haittaavien ihopoimujen vuoksi Suomessa vuosien 1998 ja 2016 välisenä aikana (Study I). Abdominoplastia oli yleisin (89 %) alavartalonmuokkaustoimenpide massiivisen laihtumisen jälkeen. Keskimäärin alavartalomuokkausleikkaus tapahtui 31 kuukautta lihavuusleikkauksen jälkeen.

Tutkimusaineistossa oli yhteensä 92 naista, jotka olivat käyneet alavartalomuokkausleikkauksessa ja tulleet tämän jälkeen raskaaksi (Study II). Tutkimusaineistoa verrattiin kaikkiin raskauksiin ja synnytyksiin Suomessa vuosien 1999 ja 2016 välisenä aikana. Yhteensä 26 naista oli käynyt

lihavuusleikkauksessa ennen alavartalomuokkausleikkausta. Alavartalomuokkausleikkauksen läpikäyneillä naisilla oli enemmän synnytyksiä keisarinleikkauksella sekä ennenaikaisia synnytyksiä, mutta nämä seikat selittyvät todennäköisesti muilla tekijöillä kuin edeltävällä vartalonmuokkaustoimenpiteellä.

Yhteensä 158 massiivisesti laihtunutta potilasta kävi alavartalomuokkausleikkauksen läpi vuosien 2009 ja 2015 välisenä aikana Töölön sairaalassa. Leikkauksen jälkeisiä komplikaatioita tilastoitiin 96 kappaletta 80:llä leikatuista potilaista. Komplikaatioprosentti oli 51. Suurin osa komplikaatioista olivat lieviä, pääsääntöisesti eriasteisia haavanparanemisongelmia, pinnallisia haavainfektioita sekä serooma kertymiä, jotka eivät vaatineet lisätoimenpiteitä (Study III).

Neljännessä osatutkimuksessa tutkittiin yhteensä 23 massiivisesti laihtuneen potilaan lihaskunto kolmella ikä ja sukupuolivalioidulla lihastestillä. Tulosten mukaan alavartalonmuokkausleikkaukseen hyväksytyillä potilailla on huonompi lihasvoima kolmessa lihaskuntotestissä verrattuna saman ikäisiin ja saman sukupuolisiin vertailuryhmiin (Study IV).

Johtopäätökset

Suomessa vain pieni osa (14.1 %) lihavuusleikatuista potilaista käy massiivisen laihtumisen jälkeen vartalonmuokkausleikkauksessa haittaavien ihopoimujen vuoksi. Vartalonmuokkausleikkaus tapahtuu keskimäärin noin kahden vuoden 7 kuukauden kuluttua lihavuusleikkauksesta.

Tämän tutkimuskokonaisuuden mukaan raskautta ja synnytystä edeltävä alavartalonmuokkaustoimenpide ei aiheuttanut merkittäviä komplikaatioita raskaana olevalle tai syntymättömälle lapselle.

Vartalonmuokkausleikkauksen jälkeiset komplikaatiot ovat yleisiä massiivisen laihtuneilla potilailla. Komplikaatiot ovat kuitenkin yleensä suhteellisen pieniä ja polikliinisesti hoidettavissa olevia. Massiivisesti laihtuneiden lihaskunto on normaaliväestöä heikompi ikä-ja sukupuolivalikoiduissa lihaskuntotesteissä.

1 INTRODUCTION

Obesity is one of the most severe public health challenges worldwide. The World Health Organization (WHO) has established obesity as a growing pandemic (Caballero, 2007). Bariatric surgery (BS), among various procedures, is the most effective treatment for severe obesity (Adams et al., 2018; Angrisani et al., 2017). BS causes significant long-term weight reduction and remission of obesity-related co-morbidities, reduced mortality, and substantial improvement in health-related quality of life (QoL) (Buchwald et al., 2004; Luca et al., 2016; Reges et al., 2018). Lifestyle modification may also lead to massive weight loss (MWL). Unfortunately, conservative treatment choices suffer from a high rate of failure at long-term follow-up and, at best, usually only slow the process of obesity and associated co-morbidities (Kissane et al., 2011; Wing et al., 2013).

Despite the many positive effects of MWL, the skin and soft tissue often lack the elasticity to conform to the reduced body size. Adult patients experience problems from redundant loose skin related to MWL at a frequency of 53–96% (Kitzinger et al., 2012a; Staalesen et al., 2014). The redundant skin can subsequently lead to functional, psychological, and social problems (Biorserud et al., 2011). Functional complaints include skin rashes, irritations, and breakdown of skin folds, leading to infections that require antibiotics and challenges in maintaining hygiene due to the weight of the abdominal pannus (Rosen et al., 2019). Symptoms following MWL because of redundant skin impact the patient's QoL, causing social isolation, impaired self-esteem, and negative body image perceptions (Gilmartin et al., 2016; Klassen et al., 2012). The extra loose skin may also make it difficult to exercise, find the right size of clothes, and carry out daily activities (Gilmartin et al., 2013; Staalesen et al., 2013). Further, redundant skin may prevent weight loss or contribute to additional weight change (Froylich et al., 2016). The loose, excess skin is most often located mid-body, although it can be present in many other regions (Biorserud et al., 2011; Song et al., 2005).

Contour deformities are resistant to exercise and diet (Colwell, 2010). Body contouring surgery (BCS) is the only competent treatment to remove redundant hanging skin. BCS after significant weight loss has risen dramatically in the last decades, following closely the rise in the prevalence of BS (Herman et al., 2015; Kitzinger et al., 2012b). Abdominoplasty is the most common procedure to reconstruct contour deformities on the lower anterior body (Song et al., 2005). If the posterior part of the lower body is also affected, a circumferential procedure, also known as a body lift, is employed (Hurwitz et al., 2016). There are numerous variations of these procedures. BCS after MWL is generally considered as a reconstructive rather than cosmetic surgery. In many developed countries, including Finland, public health care covers lower body contouring surgery (LBCS) after MWL on the condition that body deformities cause health problems.

Post-operative complication rates after LBCS are relatively high, although these operations are considered elective surgeries and thus, involve a careful risk evaluation for each patient. The overall complication rate is from 28% to 78%; however, most complications are minor (Botero et al., 2017; Hasanbegovic et al., 2014; Poodt et al., 2016; van der Beek et al., 2011).

Obesity in fertile-aged women has risen worldwide, leading to increased bariatric procedures in this group (Gimenes et al., 2017). BS has an overall positive effect on maternal and neonatal outcomes by reducing obesity-related risks (Carreau et al., 2017). Generally, LBCS has not been advised when a woman plans to become pregnant soon after the operation. The main explanation provided is that after LBCS, reduced flexibility of the abdominal wall may endanger the health of both mother and baby. Secondly, the pregnancy may hinder the aesthetic results of LBCS (Nahas, 2002). However, there is a paucity of data regarding the safety of pregnancy and delivery after LBCS.

Previous studies have consistently shown that people with MWL have poor muscle strength and reduced muscle function (Choi et al., 2016; Lafortuna et al., 2014). Sarcopenia is defined as a reduction of skeletal muscle mass, strength, and impaired muscle function (Edwards et al., 2015). Patients with sarcopenia are especially at risk with major physiological stressors, such as surgery or surgical complications.

The aim of this thesis was to evaluate patients who had reduced a significant amount of their body weight by either surgical or non-surgical means, leading to redundant loose skin around the lower body, causing a wide range of health-related problems.

2 REVIEW OF THE LITERATURE

2.1. OBESITY

Worldwide, over 1.9 billion adults were overweight (39%), and more than 650 million adults were obese (13%) in 2016, according to the World Health Organization (WHO) (World Health Organization 2020). Overweight and obesity prevalence have risen dramatically in recent decades and continue to increase. Morbid obesity (Table 1) has reached epidemic proportions in developed countries (Hruby et al., 2015). In Finland, according to the FinTerveys 2017 study, 71.9% of men were overweight (BMI > 25 kg/m^2) and 26.1% obese (BMI ≥ 30 kg/m^2), while for women, the corresponding proportions were 63.2% and 27.5% (Koponen et al., 2018).

Overweight and obesity classifications in adults are based on body mass index (BMI) as recommended by the National Institutes of Health (NIH) and the World Health Organization (WHO). BMI is the same for both sexes and all ages of adults. BMI is defined as the body mass in kilograms divided by the square of the body height in metres (Table 1).

Table 1 *Obesity classification by the National Institutes of Health (1998) and the World Health Organization (2000)*

BMI (kg/m^2)	Weight status
<18.5	Underweight
18.5–24.9	Normal weight
25.0–29.9	Overweight
30.0–34.9	Moderately obese (Class I)
35.0–39.9	Severely obese (Class II)
40–49.9	Very severely obese/Morbidly obese (Class III)

The prevalence of obesity is associated with increased incidence of such co-morbidities as type 2 diabetes mellitus (T2DM), hyperlipidaemia, hypertension, metabolic syndrome, gallbladder disease, cancer, and osteoarthritis (Boido et al., 2015; Guh et al., 2009; Seidell et al., 2015; Stefan et al., 2013). Other co-morbidities associated with overweight are cirrhosis, non-alcohol fatty liver diseases, non-alcoholic steatohepatitis, gastroesophageal reflux, asthma, polycystic ovarian syndrome, infertility, urinary incontinence, and depression (Martin-Rodriguez et al., 2015). Obesity is correlated with an increased risk for mortality (Pischon et al., 2008; Wang et al., 2011). Compared with normal-weight adults, obese adults had at least a 20% higher rate of dying of all-cause or cardiovascular diseases (Borrell et al., 2014; Freedman et al., 2006). Beyond the health risks, obesity has also been shown to have a negative impact on quality of life (QoL) (Kolotkin et al., 2017).

2.2. MASSIVE WEIGHT LOSS (MWL)

Massive weight loss (MWL) reduces co-morbidities (Brethauer et al., 2013), improves QoL (Lindekilde et al., 2015), and decreases all-cause mortality (Cardoso et al., 2017). Even weight loss in the 5–10% range can significantly improve health-related outcomes (Fruh, 2017). Bariatric surgery (BS) is the most effective treatment for morbid obesity (Adams et al., 2018; Puzziferri et al., 2014). Lifestyle changes by decreasing calories and increasing aerobic exercise could also yield weight loss results, but these are not as long-lasting as the results of BS (Douketis et al., 2005; Franz et al., 2015).

2.2.1. Non-surgical weight loss methods

Long-lasting lifestyle changes should involve all components of obesity treatment. Lifestyle changes as a treatment for obesity can consist of reduced dietary intake of calories (Samaha et al., 2003; Wadden et al., 2007), improved regular physical activity (Obert et al., 2017), behavioural changes (Butryn et al., 2011) and pharmacological therapy (Apovian et al., 2015). Many published studies have shown that non-surgical treatment options achieve weight loss only in the short term (Franz et al., 2015; Kissane et al., 2011; Terranova et al., 2015). Intense lifestyle interventions can reduce weight loss on average by 10% at one year and 5.3% at eight years (Wing et al., 2014). A Swedish study by Sjöström in 2013 demonstrated a reduced mean change in body weight of 16% in the BS group and 1% in the conservatively treated control group at the 15-year follow-up (Sjöström, 2013).

2.2.2. Bariatric surgery

BS has been demonstrated to be a safe and sustainable method of weight loss. In a large meta-analysis that included 161 756 patients, the overall complication rate after BS was 17%, and the mortality rate within 30 days was 0.08% (Chang et al., 2014). Dietary/lifestyle therapy provides <5 kg weight loss after 2–4 years, pharmacologic 5–10 kg weight loss after 1–2 years, and BS up to 25–75 kg weight loss after 2–4 years (Douketis et al., 2005). BS achieves significant improvements in the multiple co-morbidities associated with obesity (Aggarwal et al., 2016; Brethauer et al., 2013; Santos et al., 2019). BS is also associated with a significantly reduced risk of all-cause mortality among patients with BMI ≥ 35 kg/m^2 (Moussa et al., 2019).

2.2.2.1. Bariatric procedures

BS was introduced in the 1950s (Phillips and Shikora, 2018). Swedish Victor Henrikson described resection of the small intestine in 1952 (Henriksson, 1952). Edward E. Mason in the USA performed the first gastric bypass operation in 1966 (Mason et al., 1967). The surgical treatment of obesity became more common in the late 1970s. The first laparoscopic, less invasive bariatric procedure was introduced in 1993 (Wittgrove et al., 1994). The number of BS cases has risen dramatically in the last two decades. Nearly 686 000 bariatric operations were performed worldwide in 2016. Nowadays, almost all (99.3%) operations are performed laparoscopically (Angrisani et al., 2018).

Bariatric procedures are divided into the following three general categories (Wolfe et al., 2016):

- Restrictive procedures in which the size of the gastric pouch is significantly reduced, limiting caloric ingestion.
- Malabsorptive procedures in which malabsorption of nutrients provides weight loss.
- A combination of restrictive and malabsorptive categories.

Restrictive procedures

The main restrictive procedures are sleeve gastrectomy (SG), adjustable gastric band (AGB) procedures, and vertical-banded gastroplasty (Figure 1B and 1C).

Laparoscopic sleeve gastrectomy (LSG) has become the most frequently performed bariatric procedure in the world. Over half (54%) of all bariatric operations performed worldwide in 2016 were LSG procedures, comprising nearly 340 000 operations (Angrisani et al., 2018). SG is a purely restrictive procedure. Weight loss is achieved by reducing gastric volume, which leads to reduced food intake. The stomach is reduced to about 15% of its original size (Benaiges et al., 2015).

The AGB is the least invasive restrictive weight loss procedure. It represents about 3.0% of all bariatric operations (Angrisani et al., 2018). In 2006, laparoscopic AGB was the second most performed BS procedure, representing about 42% of all procedures. However, the high rates of unsatisfactory weight loss and complications have resulted in subsequent disfavour of AGB (Suter et al., 2006). The procedure involves an inflatable band placed around the upper portion of the stomach, creating a small stomach pouch above the band. The size of the stomach becomes progressively smaller (Beitner et al., 2012).

Malabsorptive procedures

Biliopancreatic diversion (BPD) (Figure 1D), jejunoileal bypass (JIP) and duodenal switch (DS) are included in the malabsorptive categories. Together, these procedures represent approximately 0.5% of all bariatric procedures worldwide (Angrisani et al., 2018). The basic principle of these procedures is that most of the nutrient absorption surface of the gastrointestinal tract is bypassed by creating an anastomosis from the proximal to the distal small intestine. These procedures achieve rapid and significant weight loss (Skogar et al., 2017). However, these approaches are in limited use due to a high risk of long-term nutritional and metabolic complications (Angrisani et al., 2018).

Combination procedures

The Roux-en-Y gastric bypass (RYGB) was the most frequently performed bariatric procedure until 2014, when it was overtaken by LSG (Figure 1E). Around 686 000 bariatric operations were performed worldwide in 2016, and about 191 000 (30%) were laparoscopic RYGB (Angrisani et al., 2018). The RYGB is a procedure with malabsorptive and restrictive features. Malabsorption with RYGB is due to the bypass of the fundus, duodenum, and proximal jejunum. The stomach size is decreased to less than 30 ml, with a length of 75–150 cm. The amount of food intake is reduced due to the small gastric pouch. By reducing the size of the stomach, the patient loses storage capacity. Elimination of the body of the stomach severely restricts the process of food pounding, which is important in releasing vitamins and minerals; this leads to maldigestion and malabsorption (Brocks et al., 2012; Hauk et al., 2018).

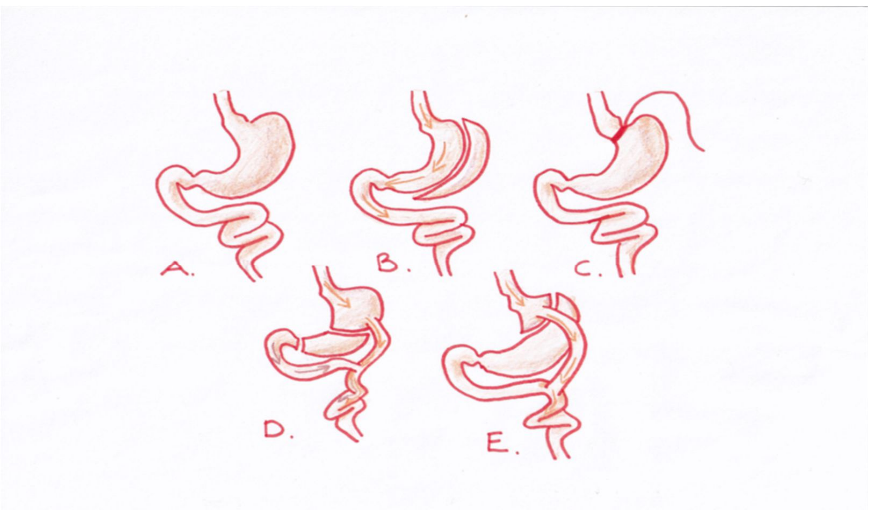

Figure 1 *A; Normal digestion B; Sleeve gastrectomy (SG), C: Adjustable gastric band (AGB), D; Biliopancreatic diversion (BPD), E; Roux-en-Y gastric bypass (RYGB)*

2.2.3. Weight loss after bariatric surgery

The mean proportion of excess weight loss was approximately 61% for all BS patients: 48% for AGB, 62% for laparoscopy RYGB, 68% for SG, and 70% for DS or BPD, according to a systemic review and meta-analysis published in 2006 (Olbers et al., 2006). BS leads to an average loss of 60–75% of additional body weight, with the highest weight loss occurring between 12 and 24 months postoperatively (Manning et al., 2015; O'Brien et al., 2013).

After a rapid weight loss period, the patient may start to gain weight again (Karmali et al., 2013; Shantavasinkul et al., 2016). An estimated 10–20% of post-BS patients regain a significant portion of their lost weight. The weight gain phase is most sensitive about two to five years after BS when many patients slowly return to old habits, and food amounts begin to increase (Odom et al., 2010; Yanos et al., 2015).

2.2.4. Quality of life after MWL

Numerous studies have reported that QoL improves significantly after MWL due to BS (Driscoll et al., 2016; Kolotkin et al., 2017; Strain et al., 2014). QoL improvements are more likely to occur during the first two years after BS (Hachem et al., 2016). In addition, the MWL reduces co-morbidities and has a positive effect on self-esteem, reducing psychological distress, including depression and poor body image (Mazer et al., 2017). In 2011, a Finnish study demonstrated that disease-specific QoL scores were significantly improved on all domains one year after the BS, and the improvement was maintained at five years (Helmiö et al., 2011).

2.3. EFFECT OF OBESITY AND WEIGHT LOSS ON SKIN

Obesity affects the quality of the skin through several mechanisms. Obesity is responsible for significant metabolic changes in the skin, sebaceous glands, sweat glands, lymphatics, collagen structure and function (Doiron et al., 2017). It is also linked to decreased cutaneous blood flow by microcirculation, macrocirculation, and impaired capillary recruitment, leading to deficiencies in the wound healing mechanism (de Jongh et al., 2004). Obesity is associated with many dermatological diseases, including erysipelas, necrotising cellulitis, folliculitis, candidiasis, lichen sclerosis, acanthosis nigrans, hidradenitis suppurativa, psoriasis, lymphoedema, and chronic venous insufficiency (Hidalgo, 2002; Jensen et al., 2016; Vazquez et al., 2013; Yosipovitch et al., 2007; Zhang et al., 2007; Zhang et al., 2017).

After MWL, the skin has a lesser ability to retract and remain soft with a significant loss of elasticity (Orpheu et al., 2010). The redundant skin can be associated with structural changes and skin pathology (Fearmonti et al., 2012). After BS, the skin has a poorly organised collagen structure, elastin degradation and scar regions within macroscopically normal areas (Light et al., 2010). The collagen is disorganised, and both collagen and elastin fibres are reduced. The vascularity may grow in stretched tissue. Extra loose skin is less dense and thinner, with increased cross-linking (Prist et al., 2017). A previous study described histomorphology differences in the skin after MWL compared with age-matched controls. Both surgical and non-surgical weight loss groups had morphologic skin changes relative to age-matched controls. However, the results were not significantly different between the surgical and non-surgical groups (Fearmonti et al., 2012).

The skin has a natural ability to retract to some degree after MWL, depending on the patient's age, length of time being overweight, and the amount and speed of total weight loss (Goddio, 1991). Skin is naturally tighter and more elastic in younger people and is often considered to be more competent in contracting, while older patients tend to exhibit a more significant amount of skin laxity (Al-Nuaimi et al., 2014). Genetic factors can also play a role in the quality of the skin (Hirt et al., 2019). The natural ability of the skin to retract is exhausted within the first year after weight loss. Further spontaneous regression is unlikely and redundant skin does not contract back to its pre-weight gain tightness.

2.3.1. Redundant skin after MWL

Redundant skin exists in areas above the zones of adherence. The superficial fascia attaches to the underlying muscular fascia throughout the body. Areas of strong superficial fascia are called zones of adherence. Obesity, weight reduction, age, gender, and sun damage have been shown to weaken fascial attachment. Lax skin consists of fat bulging over a tight zone of adherence. Also, gravity and eventual oedema will continue to pull on the fat in the loose tissue. The regions of the body most affected by excess skin tissue are the thoracic area, the breasts, abdominal wall, medial part of the upper arms, and the thighs (Agha-Mohammadi et al., 2010).

Almost all patients (70–96%) describe some problems with redundant skin due to MWL. Women usually experience redundant skin more negatively than men (Kitzinger et al., 2012a; Staalesen et al., 2014). The redundant skin is most located mid-body (25–70%), but it can be present in many other regions, e.g., breast (10–23%), upper arms (26%), and medial thighs (23%) (Biorserud et al., 2011; Gilmartin, 2013; Kitzinger et al., 2012b; Staalesen et al., 2013). In a previous study, most patients (87%) were delighted with their weight loss, although 70% considered the excess skin, or "flappy skin", to have a negative impact on appearance (Kinzl et al., 2003).

Patients with a higher pre-operative BMI and a more significant weight loss are more likely to suffer problems from redundant skin (Giordano et al., 2013; Zammerilla et al., 2014). Younger patients are not thought to sustain excess skin to the same extent as older patients (Staalesen et al., 2014). Many studies have reported higher levels of dissatisfaction with excess skin among adolescents, women, and patients with higher current BMI (Giordano et al., 2013; Staalesen et al., 2014; Steffen et al., 2012).

In the current study, patients were measured for excess skin on body parts before BS and approximately one and a half years after BS and were asked to fill in the Excess Skin Questionnaire (Biorserud et al., 2016). The prediction analysis indicated that for every centimetre of ptosis (the skin fold below the umbilicus) in the midline pre-operatively, there was a 2-fold greater probability of having postoperative ptosis of the abdomen of more than 3 cm. Further, with a weight loss of about 30%, all circumference measurements decrease as expected, but patients seem to become more aware of and disturbed and discomforted by excess skin on several body parts after weight loss. There was also a significant difference between the sexes regarding symptoms from excess skin. Men reported a significant improvement for the statement “difficulties doing sports” ($p=.011$), and women reported a significant worsening for the statement “itching and rash” ($p=.026$) and “hindrance in intimate situations” ($p= .003$) after MWL.

2.3.1.1. Health-related problems due to redundant skin

Redundant skin folds are usually heavy, bulky, and present functional, physiological, aesthetic, and psychosocial problems and can disturb mobility and daily living activities (Colwell, 2010; Herman et al., 2015). Approximately 60% of patients report that redundant skin causes problematic skin conditions, including itching, intertriginous rashes, and ulcerations (Kitzinger et al., 2012a; Mitchell et al., 2008). The redundant skin folds form a moist environment, boosting bacterial and fungal growth, which can lead to the common occurrence of candidiasis, folliculitis, eczema, and more severe infections, including erysipelas and necrotising cellulitis (Light et al., 2010; Manzoni et al., 2015; Rosen et al., 2019). Skin folds are hard to keep hygienic, causing, for instance, unpleasant odour.

The redundant skin can cause back and neck pain, complicating physical activity (Grindel et al., 2006; Staalesen et al., 2013). An estimated 77% of women who underwent BS have mobility limitations due to redundant skin during physical activity, and 45% stated avoiding physical activity due to redundant skin. Women also reported flapping of skin and harsh stares from others. Walking, running, bending, and getting up are described as the most limited movements due to redundant skin folds (Baillot et al.,2013).

2.3.1.2. Psychological aspects of redundant skin

Shame, low self-esteem, and poor body image are common psychological side effects after MWL due to redundant skin. Patients have described being ashamed and embarrassed by their appearance (de Zwaan et al., 2014; Kinzl et al., 2003; Sarwer et al., 2008). These side effects may lead to social isolation (Klassen et al., 2012). Patients report difficulties finding well-fitting clothes and modifying their behaviour to hide their hanging skin (Aldaqal et al., 2013;

Biorserud et al., 2011; Klassen et al., 2012). Intimacy and sexual relationships are also affected by feelings of shame and poor body image (Gilmartin, 2013; Toma et al., 2018). Redundant skin affects mood, making patients feel depressed and highly self-conscious about their appearance, which may be linked secondarily to weight regain (Chandawarkar, 2006; Klassen et al., 2012; van Gemert et al., 1998). Up to 68% of patients with redundant skin were reported to avoid bathing at public beaches or swimming pools, wearing a swimsuit, or exposing a bare upper body. Places and activities that required nakedness in front of others, like a public sauna, were also avoided (Biorserud et al., 2011). Higher BMI and more excess skin are linked to lower satisfaction with appearance and decreased health-related QoL (Poulsen et al., 2017).

2.3.1.3. Classification of skin deformities

The deformities include unexpected manifestations that potentially involve every area of the body. The severity of the outstanding contour deformities varies per individual, depending on age, gender, pre-operative presence and amount of total weight loss, among others. Also, the plastic surgeon's view of the severity of the deformities differs. The classification system is a valuable method for systematically evaluating a patient and describing the deformities in an adaptable manner from surgeon to surgeon. It offers information about the extent of the disease to guide treatment and provide estimates of prognosis. The classification system also provides a standardised outline for scientific reporting and is an essential step in developing guidelines for the treatment of MWL patients.

Many classification systems have been developed that address deformities in different parts of the body (Iglesias et al., 2010; Zammerilla et al., 2014). Pittsburgh Rating Scale (PRS) is a validated classification system of skin deformities following MWL (Song et al., 2005; van der Beek et al., 2013). The PRS grading is a subjective quantification of the extent of surgical deformity in each of eight different body regions. The PRS is a 4-point scale based on region-specific grading criteria in areas of the body most frequently demonstrating laxity and ptosis (de Vries et al., 2020).

2.4. DEVELOPMENT OF BODY CONTOURING SURGERY (BCS)

BCS techniques have developed since the first procedure was performed more than 120 years ago (O'Toole et al., 2006). In 1890, the French surgeons Demars and Marx reported a significant skin and fat resection from the abdomen with removing the umbilicus (Demars et al., 1890). The first reported abdominoplasty/lipectomy was performed by Kelly, an American surgeon, in 1899. He described using a horizontal mid-abdominal incision with resection of 7450 grams (Kelly, 1899). Peters described in 1901 a similar surgery, extracting the same resection amount, including the umbilicus, without the undermining (Peters, 1901). Gaudent and Morestin introduced in the French Congress of Surgeons in 1905 an extensive transverse incision to correct an abdominal wall hernia (Gaudent F, Morestin, 1905). Babcock described dermatolipectomies using a vertical incision (Babcock. W, 1916). The earliest work by these surgeons and others generally represents truly functional panniculectomies. Deviation occurred in scar location and morphology, but the basic approach was the same, simple dermatolipectomy.

In 1924, Thorek performed the first lower abdominal transverse incision with umbilicus-preserving abdominoplasty (Thorek, 1924). Despite the numerous incisions described during the first half of the 19th century, the lower abdominal incision by Thorek became the approach of choice. He is praised for the contour surgery's first major aesthetic accomplishment.

In the 1950s, Vernon contributed to a new era when he created a procedure by combining extensive undermining with umbilicus transposition and relocation (Vernon, 1957). This particular procedure is still in use today. Callia described aponeurotic suturing, which involved an infrainguinal incision in 1967. Grazer defended in 1973 the "bikini line" incision frequently used nowadays (Grazer, 1973). The first circumferential dermolipectomy was introduced by Somalo in 1942 (Somalo. M, 1942). In the 1960s, Gonzales-Ulloa and Vilain were ascribed the first belt lipectomy/circular lipectomy technique with a posterior scar located at the belt line (Gonzalez-Ulloa, 1960).

Lockwood described the lower body lift in 1993, which merged the medial thigh lift with the transverse thigh-buttock lift, and moreover, featured two significant innovations: a resection that preserved the superficial fascia and a lower-sited scar to help lift the lateral thigh and buttocks (Lockwood, 1993). Lockwood's first lower body lift was indicated for normal-weight patients. Carwell was the first surgeon to include post-bariatric patients (Carwell et al., 1997).

2.5. DESIRE FOR BCS

From 25% to 88% of patients with MWL desire BCS (Aldaqal et al., 2012; Gusenoff et al., 2008; Staalesen et al., 2013). A Finnish study evaluated 360 patients' preferences for BCS after BS; up to 80% of patients desired contouring to several parts of the body. Most patients highly or very highly desired body contouring for the waist/abdomen (62.2%), upper arm (37.6%), chest/breast (28.3%), and rear/buttock (35.6%) (Giordano et al., 2014). An estimated 9–15.5% of post-bariatric patients do not want any contouring procedure after MWL (Giordano et al., 2014; Wagenblast et al., 2014).

Women usually have a stronger desire for BCS than men (Giordano et al., 2014; Sioka et al., 2015). A recent study discovered that 75% of females and 68% of males were interested in BCS following MWL (Kitzinger et al., 2012a). A significant association has been found between the desire for BCS and younger age, amount of weight loss, and difference in BMI (Giordano et al., 2014; Gusenoff et al., 2008; Singh et al., 2012). Divorced patients are twice as likely to favour body contouring than married patients (Gusenoff et al., 2008). Psychosocial factors seem to influence the desire for BCS after MWL. Patients who desire BCS have a more negative body image and more depressive symptoms than patients without this desire or who have already had BCS. Patients who are not interested in BCS are less focused on their appearance and less preoccupied with overweight cognitions than their counterparts who have already had BCS or desire procedure (Monpellier et al., 2018). The longer the period from BS, the less likely the patients are to desire BCS (Steffen et al., 2012).

2.6. PREVALENCE OF BCS AFTER MWL

The prevalence of BCS after MWL has ranged from 7% to 25% (Aldaqal et al., 2012; Kitzinger et al., 2012b; Lazzati et al., 2018; Romano et al., 2019). In total, 926 patients were examined 2-16 years after RYGB (Gusenoff et al., 2008). Only 11.3% of all patients underwent BCS afterwards. Another study demonstrated a figure as high as 47% of all post-bariatric patients received BCS 6–10 years after RYGB (Mitchell et al., 2008). A large database included 37 806 patients who underwent BS; analysis revealed that no more than 5.6% of patients subsequently had any contouring surgery (Altieri et al., 2017).

Approximately 80% of all patients who undergo BCS after MWL are women (Kitzinger et al., 2012b). Women have a 2-fold probability for BCS compared with men. BCS after MWL is less common among younger (< 30 years) or older patients (> 60 years) than among middle-aged patients (30-60 years) (Lazzati et al., 2018). In 2009, a report was published concerning the surgical treatment of morbidly obese individuals in Finland. According to this report, 7% of all post-bariatric patients underwent BCS between 2000 and 2007. However, this report did not specify the inclusion or exclusion criteria for BCS, nor did it categorise the body contouring methods (Ikonen et al., 2009).

The American Society of Plastic Surgeons reported 23 206 abdominoplasty procedures after MWL in 2018 and 21 188 procedures in 2019, which is 9% less than the preceding year. Also, the breast lift after MWL decreased by 9%. Other BCS after MWL had risen; lower body lift and tight lift increased by 3% and upper arm lift by up to 9%. Overall, the total number of BCS after MWL had decreased by 5% in one year (American Society of Plastic Surgery, 2019).

2.7. TECHNIQUES IN BCS AFTER MWL

The main goal of BCS after MWL is to optimise and improve both the functional and aesthetic outcomes by removing excess skin and soft tissue and, if necessary, repositioning the myoaponeurotic layer. The most commonly performed body contouring procedure is abdominoplasty (36–62%), followed by body lift (20%), brachioplasty (3.5-12%), breast lift (8.7-14%), thigh lift (7-9%), and liposuction (2%) (Kitzinger et al., 2012b; Lazzati et al., 2018). The incidence of contouring procedures seems to vary by gender. In the questionnaire surveys, female patients reported a higher incidence of brachioplasties and body lifts, while male patients reported a higher incidence of procedures focusing on lifting the upper body (Ahmed et al., 2018; Chong et al., 2012).

Combined or multistage operations are sometimes recommended for MWL patients due to severe skin and soft tissue sagging all over the body (Anlatıcı et al., 2018; Maia et al., 2017). No single procedure can address whole-body deformities. The average number of contouring procedures per post-bariatric patient is one to two. To reduce the numbers of surgeries, a concomitant body contouring surgery is commonly performed (Zammerilla et al., 2014). Chong et al. discovered in 2012 that 60% of BCS patients after BS undergo a single body contouring procedure that addresses multiple body areas, with abdominoplasty and breast contouring being the most common combination.

2.7.1. Lower body contouring surgery (LBCS)

The lower body is described as the location with the most severe deformities after MWL (Gilmartin, 2013; Kitzinger et al., 2012b; Staalesen et al., 2013). The abdominoplasty is usually among the first procedures to be performed (Figure 2). Abdominoplasty and body lift account for nearly 62% of all contouring procedures (Lazzati et al., 2018).

The lower body contouring procedures focus on the abdomen, lower back, and buttock area. Post-bariatric body contouring covers not only the reconstruction of structural integrity but also aesthetic body contouring. The reconstructive goals are to resection loose extra skin and superficial subcutaneous adipose tissue, re-establish appropriate anatomy of the rectus muscles, and correct diastasis if necessary. The aesthetic goals of LBCS are to improve the contour of the abdominal wall to minimise scarring and maintain a natural-appearing umbilicus. Both reconstructive and aesthetic purposes should be included in any LBCS.

To ensure the best aesthetic results and optimal wound healing, the weight should be stable for at least 6 to 12 months before any BCS. Weight stability implies a return to an anabolic state and improved surgical safety. The average time to LBCS after BS is 2–3 years (Altieri et al., 2017; Kitzinger et al., 2012b). In one study, the rates of BCS were 13% at three years, 18% at five years, and 21% at seven years after BS (Lazzati et al., 2018).

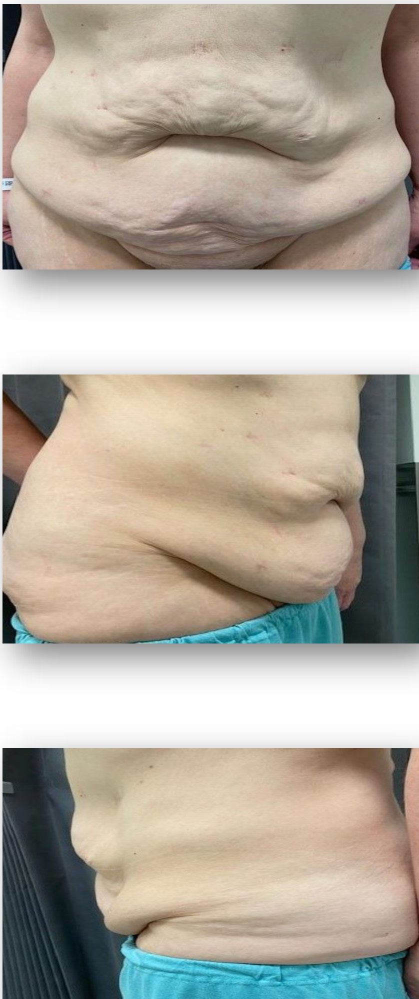

Figure 2 *Frontal, right anterior oblique and left clinical views of the 56-year-old woman with abdominal deformity following MWL. She has undergone BS three years earlier and has lost 35 kg of her body weight. Current pre-operative BMI was 28.3* km/m^2*. The pictures were taken a day of LBCS*

2.7.2. Anatomy

The lower body presents significant anatomical and functional changes in patients with previous MWL. Knowledge of the normal anatomy and familiarity with the delicate contour of the anterior and posterior lower body wall will allow effective decision-making regarding what can be improved with LBCS (Almutairi et al., 2016).

Anatomic landmarks

The abdomen is the part of the trunk situated between the thorax and the pelvis. The upper limits are the lower ribs and the xiphoid process. Inferiorly, it is limited by the pubis and the inguinal folds, and the lateral limits correspond to the midaxillary lines (Centano et al., 2006; Hurwitz, 2015).

Subcutaneous and myoaponeuratic anatomy of the abdominal wall

Two different soft tissue compartments exist in the lower abdominal wall. The superficial and deep compartments are separated by a layer of membranous tissue called the Scarpa fascia. In the superficial layer, the adipose tissue is thick and dense. Fat is loose in the deep layer.

The lower trunk has fascial attachments between the skin and underlying muscle fascia that act as an attachment point or zone of adherence. In the correlation of loose, excess skin, it is important to be familiar with this fascial attachment system. The points do not allow overlying skin to move during processes of weight fluctuations or pregnancies. Posteriorly, the midline has a zone of adherence that overlies the spine. The anterior midline of the abdomen has a less defined zone of adherence. Three horizontal zones of adherence are located in the inferior aspect of the lower trunk: at the inguinal region bilaterally and extending towards the anterior superior iliac spine, the mons pubis, and between the hip and lateral thigh fat deposit (Taylor 2017).

There are two rectus abdominis muscles and six flat muscles; the external oblique muscles, the internal oblique muscles, and the transverse muscles comprise the anterior lateral aspect of the abdominal wall. The rectus abdominis muscles are enfolded by two aponeuroses: the anterior and posterior rectus sheath. Above the arcuate line, the anterior sheath is formed by aponeurotic fibres originating from the external and internal oblique muscles. Below the arcuate line, the external, internal, and transverse aponeuroses combine to form the anterior rectus sheath (Sobotta 1989; Rosen 2017).

Circulation

The skin overlying the rectus muscles is primarily supplied by arteries that originate from the superior and inferior epigastric arteries running along with the rectus muscles. Branches from these vessels perforate the overlying rectus fascia and transverse through the two layers of abdominal fat, finally reaching the skin. A secondary blood supply is derived from the lateral intercostal, subcostal, and lumbar vessels that course anteriorly in the fat superficial to the Scarpa fascia. The superficial epigastric vessels supply blood to the skin of the lower abdomen (Atijeh et al., 2012).

Lymphatic system

The lymphatic system of the subcutaneous tissue in the supraumbilical area drains to the axillary lymph nodes, and the infraumbilical system drains to the superficial inguinal lymph nodes. The infraumbilical area may also drain to the deep lymph nodes located inside the abdominal cavity. The periumbilical area drains to the deep abdominal periaortic lymph nodes (Tourani et al., 2013)

The sensory innervation

The sensitive innervation of the abdominal wall follows a segmental dermatome pattern. The intercostal (branches originating from T7 to T11), subcostal (T12), iliohypogastric (T12 and L1), and ilioinguinal (L1) nerves are responsible for the sensitive innervation of the anterior abdominal wall. Branches from T7 to T9 innervate the supraumbilical area, T10 innervates the periumbilical region, and T12 to L1 provides innervation to the infraumbilical area (Atijeh et al., 2012; Sobotta 1989).

2.7.3. Abdominoplasty

Abdominoplasty techniques may be performed using a transverse (classic), vertical, or anchor line ("Fleur-de-lis") incision (Atijeh et al., 2012). The aim of the classic or full abdominoplasty is to reshape the abdominal wall by removing significant excess skin and subcutaneous tissue with or without plication of the rectus fascia in case of rectus muscle diastasis. Some of this excess remains typically in the lateral areas as well (Matarasso et al., 2014; Regan and Casaubon, 2020). Pre-operative markings should be done with patients standing to avoid shifting the tissues from one side to another, preventing symmetrical markings (Figure 3). Procedures are performed under general anaesthesia, and the administration of preoperative prophylactic antibiotics is often used (Sevin et al., 2006; Ariyan et al.; 2015 Shestak et al., 2019).

Figure 3 *Frontal views of a 48-year-old female with pre-operative markings of conventional abdominoplasty, who lost 32 kg of her body weight after BS. The markings include the vertical median line, two transverse lines placed at the inguinal fold, and the umbilicus upper limit. The resection consists of an elliptical transverse skin shape from the hypogastrium*

The low transverse incision commonly placed just below in the inguinal folds is the most widely used but can vary according to patient needs (Figure 3). It is easily hidden beneath the underwear. The lower incision line should never be closer than 5-7 cm to the anterior vulvar commissure (Rubin 2013, Pechter 2010). The abdominal skin flap is elevated off the rectus sheath from the pubis to the xiphoid processes, preserving the umbilical stalk (Figure 4). The classic technique of abdominoplasty is performed using the prefascial plane for dissection. Using a more superficial plane of dissection has been proposed to reduce complications associated with abdominoplasty, especially seroma formation (Costa-Ferreira et al., 2010). The direct blood supply of abdominal skin is interrupted during the elevation of the abdominal flap. If the rectus diastasis is presented, the musculoaponeurotic fascia is plicate in the midline, and the lower aspect of the skin flap is resected (Boudreault et al., 2019; Tadiparthi et al., 2011). The umbilicus is placed at the intersection of a line connecting the highest point of the iliac crest with a line bisecting the abdomen from the sternum to the pubis. The new superior margin of the skin flap is sutured to the original inferior margin (Figure 5) (Almutairi et al., 2016; Avelar et al., 2016; Gutowski 2018; Rubin 2103). Two suction drains are recommended to be placed before wound closure (Bercial et al., 2011; Dutot et al., 2018; Matarasso et al., 2014). Mobilisation is usually begun on the first post-operative day. Compression garments should be worn for 4-8 weeks post-operatively, initially around the clock (Di Martinon et al., 2015; Kokosis et al., 2018).

Figure 4 *Intraoperative view of the conventional abdominoplasty with an elevation of the upper flap and wide-undermining up to the xiphoid process. In the middle line, the dissection is performed on the muscular fascia plane with the preservation of the umbilical stalk. The Scarpa fascia prevents it on the lateral side. The blue pen marks show the width of the rectus diastasis*

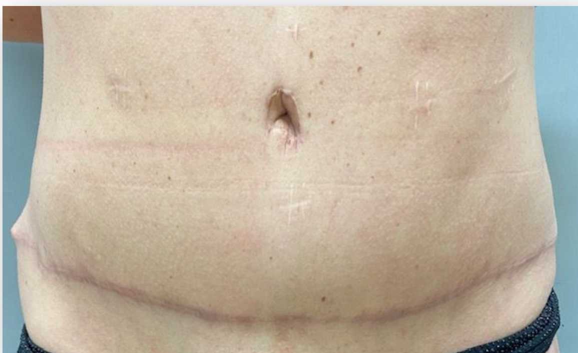

Figure 5 *6 months postoperative front view of a 35-year-old female patient after abdominoplasty*

2.7.4. Body lift

Technique variations that have been used for circumferential lower truncal procedures include circular lipectomy (Morales et al., 2003), beltlipectomy (Heddens, 2001), circumferential abdominoplasty (Modolin et al., 2003), extended abdominoplasty (Shestak, 2014), central body lift (Rohrich et al., 2006) and mid-body lift (Strauch et al., 2006). All of these terms derive from the lower body lift depending on the level of posterior resection.

If circumferential skin and soft tissue laxity are also present, body lift procedures are usually required to address the deformities sufficiently. The primary goal of the body lift is to improve the contour of the inferior truncal circumferential unit, which may include the abdomen, pubis, back, inner thigh, outer thigh, and buttock area (Carloni et al., 2016). The body lift is a more extensive version of abdominoplasty that also involves folds from the back, the third superior of the thigh, and the gluteal region (Carloni et al., 2016; Losco et al., 2020). The incision pattern extends to the back and buttock regions on both sides and anteriorly, the pattern joining the abdominoplasty scar. On the posterior side, the resection extends to the muscular fascia (Kitzinger et al., 2013; Nemerofsky et al., 2006). The operation is mainly performed with the patient first in prone, then the supine position (Kolker et al., 2009; Vico et al., 2010).

2.7.5. Panniculectomy

Panniculectomy is indicated in patients who are morbidly obese (BMI > 35 kg/m^2), even though they may have had a significant weight reduction (Sachs et al., 2020). A large, heavy pannus can interfere with daily activities, and patients are severely restricted by physical limitations, pain, rashes or superficial skin infections. During panniculectomy, the heavy pannus, including excess skin and subcutaneous tissue, are removed with conservative undermining (Atiyeh et al., 2012, Pestana et al., 2014). However, after panniculectomy, the aesthetic result is often less satisfactory than conventional abdominoplasty (Leahy et al., 2008, Mioton et al., 2013).

2.7.6. Other body contouring surgery

Liposuction

Both abdominoplasty and body lift may be performed in conjunction with liposuction to remove excess fat from the flanks and hips (Bertheuil et al., 2017; Brauman et al., 2018). Lipoabdominoplasty was developed by Saldanha in 2000 and is called the Saldanha"s technique (Saldanha et al., 2010). The amount of liposuction varies greatly depending on the desired result and the amount of tissue resected.

Breast deformities and surgery after MWL

Breast deformities are often present in MWL patients. Weight loss results in significant breast volume reduction, ptosis, lateral excess of tissue, variation in the nipple-areola complex, and emptying of the upper breast pole (Coriddi et al., 2011). Breast deformities can be treated with various surgical techniques, which should be individualised according to patient characteristics and the available breast volume (Hamdi et al., 2009). Mastopexy and mammoplasty techniques have been utilised to address the deformity of breasts with sufficient volume (Rubin et al., 2009). Implant augmentation can be required for patients who have completely flattened breasts after MWL (Hamdi et al., 2009).

Brachioplasty

Brachioplasty aims to remove excess skin and adipose tissue from the upper and, most commonly, the inner arms (Nguyen et al., 2016). Patients feel uncomfortable about their upper extremities due to the movement of hanging tissue, and the deformities can affect the lateral chest wall (Hurwitz 2014). The procedure generally starts with circumferential liposuction, and skin excess is later excised (Neaman et al., 2011; Pascal et al., 2005). Of the treated patients, 94% reported improved self-esteem and comfortable wearing short-sleeved shirts, stating that they would undergo the procedure again (Symbas et al., 2010).

Medial Thigh lift

The excess deflated skin of the inner thighs often hangs in folds and is in contact with the folds of the contralateral thigh, leading to irritation and even blisters (di Pietro et al., 2019). Redundant skin around the inner thigh also interferes with everyday activities, like walking and hygiene (Bruschi et al., 2009). The lower body lift typically addresses the lateral thighs. The medial thigh lift can be constructed to treat different amounts of skin laxity of the inner thighs. However, there are many technical variations of the medial thigh lift (Gusenoff et al., 2015). Excess skin and fat could be removed in the direct incision, and it is often combined with liposuction (Aboueldahab, 2013; Bertheuil et al., 2017).

2.8. PATIENT SELECTION AND INFORMATION

All body contouring operations are considered elective procedures. Therefore, it is especially important to minimise possible risk factors, and the patients must be selected carefully. The combination of proper patient selection and managing patient expectations is the basis for a safe LBCS. Patients seek BCS after MWL because of concerns about the appearance of different parts of their body and the effects on their psychosocial well-being and physical ability to carry out daily life activities (Al-Hadithy et al., 2014). It is important to inform the patient carefully about the risks and limitations of plastic surgery in order to limit high, often unrealistic, expectations of body contouring (Kinzl et al., 2003). Giordano et al. found in 2013 that 36.4% of MWL patients cite "very high" expectations for how body contouring might change their appearance. Even minor complications can negatively affect patients' satisfaction if they are not effectively counselled (Montemurro et al., 2015).

A previous study described the expectations of patients for contouring surgery to include improved appearance, QoL, and ability to be physically active. These expectations were identical for women and men. Further improvements to sexual pleasure were of minor importance to both sexes. Women were more concerned with finding properly fitting clothes than men (Kitzinger et al., 2012a).

Strong evidence links severe obesity and psychiatric illnesses (Chao et al., 2019; Luppino et al., 2010). Body dysmorphic disorder (BDD) is defined as an obsession with a slight or imagined defect in appearance that leads to significant distress or impairment in social, occupational, or other areas of functioning (Ribeiro, 2017; Sarwer et al., 2016). BCS is most frequently sought by patients with BDD (de Brito et al., 2016). If treated, this could lead to an unnecessary commitment to plastic surgery. If signs of BDD are discovered during the plastic surgery outpatient clinic visit, the patient should be evaluated by a specialist (Dyl et al., 2006; Phillips et al., 2010). Proper psychosocial evaluation and management of these patients are believed to play an essential role in successful post-operative results (Coon et al., 2009, Greco et al., 2008a).

2.8.1. Body mass index as a predictor of LBCS outcome

There is evidence that current residual obesity by high BMI at the time of LBCS is a predictor not only of the aesthetic outcome but also of higher rates of both minor and major complications (Coon et al., 2010; Gupta et al., 2016; Neaman et al., 2007; Poodt et al., 2016; van der Beek et al., 2011). It is important to understand that LBCS is not an alternative to weight loss; it is a complementary procedure in the weight loss process.

There are conflicting results in the literature regarding the BMI threshold above which significant complications occur, and the operation should be denied. Further, BMI criteria for BCS vary. No single number has proven valid in the surgical literature (Coon et al., 2009; Greco et al., 2008). Patients with a BMI of 30 kg/m^2 or more compared with non-obese patients are at increased risk for both minor and major complications but also tended to have a thicker subcutaneous adipose layer, which can limit effective body contouring (Gupta et al., 2016; Momeni et al., 2009; Neaman et al., 2007; Poodt et al., 2016).

Van der Beek et al. analysed in 2011 a total of 61 patients who underwent BCS after MWL. The patients were divided into four categories based on their current BMI. Obese (BMI >30 kg/m^2) patients had a significantly increased complication risk compared with non-obese (BMI <30 kg/m^2) patients (42.3% vs. 19.5%; p<.005). Also, patients with a complicated BCS had a significantly higher BMI than patients with an uncomplicated procedure (33.5 vs 28.7 kg/m^2; p<.0005). Controversial results were published by Rosa et al., 2019a, who reported the outcomes of 207 patients with preceding RYGB. The prevalence of post-operative complication rates was not significantly different between patients with BMI >30 kg/m^2 and patients with BMI < 30 kg/m^2 (33.3% vs. 25.9%; p=.344). One study has shown that BMI > 25 kg/m^2 multiplied the risk of complications (Arthurs et al., 2007).

Nemerofsky et al. (2006) evaluated 200 patients who underwent body lift alone or combined with other contour procedures. The patients were classified into three types according to their BMI at the time of surgery: Type I BMI < 28 kg/m^2, Type II BMI between 28 kg/m^2 and 32 kg/m^2, and Type III BMI < 32 kg/m^2. The overall complication rate was 50%. Type I and II patients, in many cases, received a nearly ideal body contour. Type II and III patients also had significant functional and cosmetic improvement but were more likely to have complications.

2.8.2. Weight stabilisation before LBCS

As a general rule, body contouring operations should not be performed before weight loss is complete and the weight has stabilised for at least 12–18 months (Colwell et al., 2008; Hasanbegovic et al., 2014). Most weight loss occurs during the first year after BS (Courcoulas et al., 2015; Manning et al., 2015). Some studies have reported 20–25% initial weight loss continuing after the first year and then reaching a plateau or slightly increasing at three years (Alhamdani et al., 2012; Magro et al., 2008; O'Brien et al., 2013). However, excessive weight regains (defined as ≥ 25% of total weight lost) occurred in one-third of post-bariatric patients (Cooper et al., 2015, Magro et al., 2008).

2.8.3. Assessment for co-morbidities and medical history

Severe health problems in a patient are one contraindication for BCS. Although BS and MWL can positively improve obesity-related disorders, complete elimination of these co-morbidities might not occur (Davision et al., 2008; Rubin et al., 2009). Overall, the patients are mostly healthier than when they were obese. However, post-bariatric patients differ from patients who used exercise as a means for weight decline. In the former group, cardiopulmonary status has not strengthened over time compared with those who used lifestyle modifications as a means for weight reduction (Sanger et al., 2006). The risk for overall post-operative complications is significantly increased in patients with T2DM and cardiovascular diseases (Hunecke et al., 2019; Neaman et al., 2007).

ASA classification

The American Society of Anaesthesiologists (ASA) classification is an imprecise guide to the clinical health of a patient and a predictor of aesthetic and surgical patient risk (Doyle et al., 2020). The ASA score is based on five classes depending on patients' overall health, and it has been demonstrated to be a predictor of risk for the development of postoperative complications (Derickson et al., 2018; Greco et al., 2008; Rosa et al., 2019a). It has been suggested that BCS be limited to patients with ASA grades 1 (healthy) or 2 (mild systemic disease) (Rohrich et al., 2006). ASA grade above 3 is an independent risk factor for re-admission after abdominoplasty (Massenburg et al., 2015).

2.8.4. Nutritional deficiencies

Patients who undergo BS have nutritional needs that are different from those of other patients. Nutritional deficiencies are presumed to be present in 25–50% of BS patients and are not limited to those undergoing malabsorptive procedures (Agha-Mohammadi et al., 2008; Song et al., 2008). BS markedly affects nutritional intake and reduces nutrient absorption (Via et al., 2017). Moreover, patients with preceding MWL tend to consume a poorly balanced diet. There is a significant risk of malnutrition, ranging from micronutrient deficiencies in D-vitamin, B12-vitamin, thiamine, folate, and calcium to severe protein-calorie malnutrition (Herman et al., 2015; Stein et al., 2014). The prevalence of iron deficiency varies between 1% and 54% after BS (Steenackers et al., 2018). These nutritional changes occur not only because of changes in the gastrointestinal tract but also because patients change their dietary habits and nutritional behaviour patterns after BS (Aron-Wisnewsky et al., 2016; Laurenius et al., 2013). The deficiencies are highest in the first year following BS. These deficiencies must be considered when considering BCS and play an important role in wound healing complications and may also lead to other complications after contouring surgery (Agha-Mohammadi et al., 2008).

2.8.5. Smoking

Smokers have a significantly higher risk of all kinds of post-operative complications, especially wound dehiscence, haematoma, skin necrosis, infections, and venous thromboembolism, than non-smokers after BCS (Gusenoff et al., 2008; Neaman et al., 2007; Sharif-Kashani et al., 2016; Theocharidis et al., 2018). A previous study examined 132 patients (53.8% smokers) who underwent abdominoplasties. A marked difference in wound healing emerged between smokers (47.9%) and non-smokers (14.8%) (Manassa et al., 2003). A 12-fold increase in infectious complications in smokers who underwent abdominoplasty (Araco et al., 2008). However, not all studies have confirmed this difference; Winocour et al. (2015) did not find smoking a significant risk factor for major complications (4.5% vs 3.9%; p=.23).

A considerable variation in recommended smoking cessation time pre- and post-operatively has been reported in the literature. Some studies have recommended a pre-operative smoking cessation period of at least two but preferably 12 weeks, and post-operatively from 2 to 4 weeks to optimise surgical conditions without heightening complication and aesthetic risk (Pluvy et al., 2015; Saboye, 2015).

2.9. FUNDING OF LBCS

In Finland, post-bariatric LBCS is covered by the public health care system. BCS that targets the breast, upper arms, or thighs is mainly not included in public health care. Post-bariatric LBCS is considered a reconstructive surgery, and access to treatment is provided to patients who meet specified criteria. The criteria may vary depending on the surgeon and the hospital district. In general, LBCS is indicated if redundant skin causes functional problems or repeated use of health care services or the need for daily medicine for skin diseases. BMI must be ≤30 kg/m^2, and weight loss must be completed and stabilised for at least 6 to 12 months. Non-smoking status is usually required.

In many countries, BCS after MWL is still considered a cosmetic procedure. Therefore, the public health care system denies patients who may need or desire to undergo post-bariatric BCS. Socio-economic factors may play an influential role in BCS prevalence in many countries (Gusenoff et al., 2008).

2.10. QUALITY OF LIFE AFTER BCS

Several studies have revealed a significant positive association between BCS and QoL (de Zwaan et al., 2014; Klassen et al., 2012; Lazar et al., 2009; Pecori et al., 2007). BCS improves QoL particularly by increasing self-image, improving self-esteem, lowering physical symptoms, and improving sexual relations (Biörserud et al., 2018; Gilmartin et al., 2016; Migliori et al., 2006). BCS also increases physical activity (Cai et al., 2019).

A systematic review and meta-analysis, including 13 studies, established that BCS after BS improves numerous indicators of QoL, including physical functioning, psychological well-being, and social functioning (Toma et al., 2018). Modarressi and colleagues analysed in their prospective study the role of post-bariatric BCS in long-term QoL. Ninety-eight patients who had body contouring after RYGB for severe obesity (BMI >40 kg/m^2) were included. A matched control group contained 102 patients who only had RYGB. Overall, 57% of the patients who had undergone BCS evaluated their QoL as “much better” compared with only 22% of patients who had not undergone BCS (p<.001) (Modarressi et al., 2013).

2.11. WEIGHT CONTROL AFTER BCS

Patients who undergo BCS after BS have improved long-term weight loss and control compared with patients who do not undergo BCS after BS (Balague et al., 2013; de Vries et al., 2019; Smith et al., 2018). Also, their total weight loss percentages are higher than those not undergoing BCS (de Zwaan et al., 2014). A matched control study had 186 patients who underwent BCS after BS. After a matched follow-up period of 61 months, the proportion of total weight loss was 30.8 kg ± 11.4% in the body contouring group and 24.0 kg ± 13.2% in the control group ($p<.001$) (Froylich et al., 2015). Balague et al. came in 2013 to the same conclusion that patients with BCS have improved long-term weight control after RYGB. Patients who underwent RYGB only presented significantly higher mean weight regain than patients with RYGB following BCS after seven years (1.78 kg/year (10.8%) vs 0.51 kg/year (3.6%) mean weight gain; $p<.001$). Patients accepted for BCS continue to tend to lose weight positively over the years, while patients rejected for BCS show weight regain over the same period (de Vries et al., 2019).

2.12. PREGNANCY AND DELIVERY AFTER BARIATRIC SURGERY AND LBCS

Overweight and obesity during pregnancy appear to be associated with an increased risk for many pregnancy complications, including gestation diabetes mellitus (GDM), pregnancy-induced hypertension, spontaneous miscarriage, Caesarean section, preterm birth, and foetal macrosomia, compared with those with normal BMI (Akhter et al., 2019; Carreau et al., 2017; Johansson et al., 2015). BS is most often performed in women of childbearing age (Harreiter et al., 2018; Kjaer et al., 2013). Numerous research papers have reported that BS has an overall encouraging benefit on maternal and neonatal consequences of reducing the risk of GDM, hypertensive disorders, maternal complications during delivery, foetal macrosomia, and preterm delivery (Galazis et al., 2014; Lesko et al., 2012; Sheiner et al., 2004; Stephansson et al., 2018). Further, there are contradictory results whether the BS is an independent risk factor for cesarean section (Slater et al., 2017). However, it may be challenging to determine whether BS affects the risk of Caesarean section, as the mode of delivery may be more governed by local guidelines (Gautam et al., 2008). A meta-analysis in 2014 revealed that BS is associated with a 28% increase in preterm delivery (Galazis et al., 2014).

Nutritional deficiencies and calorie malnutrition are common following BS and may be further impaired during pregnancy (Slater et al., 2017). Iron deficiency has been associated with preterm birth and calcium deficiency with birth weight (Gautam et al., 2008). In general, women have been advised to avoid pregnancy for at least 12 months (preferably two years) following BS (Parent et al., 2017).

There are very few publications concerning the effect of LBCS on subsequent pregnancy and deliveries. The literature review revealed four publications on this topic; three were case reports, and one was a congress abstract (Table 2). One of the concerns regarding pregnancy after LBCS has been the reduced flexibility of the abdominal wall, which may endanger the health of both mother and child (Borman, 2002; Nahas et al., 2011). An additional issue has been that pregnancy after LBCS could diminish the aesthetic result of the operation.

Table 2 *Literature review of the effect of LBCS on pregnancy and delivery*

The first author, Year	Type of study	Procedures	The latency between BCS and pregnancy	Mode of delivery	The outcome, remarks.
Menz, 1996	Case report	Abdominoplasty+ rectus plication	5 years	Caesarean section	No adverse effect to abdominoplasty wounds
Borman, 2002	Case report	Abdominoplasty	2 months	NA*	1 year after delivery, the abdominal wall had regained tone like after abdominoplasty
Nahas, 2002	Case report	Abdominoplasty + rectus plication	23 months	NA*	4 months after delivery, no rectus diastasis, good improvement of the abdominal contour without the need for any other abdominal procedure
Pimental, 2016	Congress abstract	Abdominoplasty	NA*	caesarean section and vaginal delivery	Caesarean section in 49 %

(* NA not available)

2.13. CLAVIEN-DINDO CLASSIFICATION

Post-operative complications are critical outcome measures in studies of surgical procedures. Both the type and severity of complications should be clearly described. Also, for a valuable quality evaluation, the relevant outcome data must be derived using a standardized and reproducible approach to allow comparison between different centres and countries and between various therapies and surgical managements (Dindo et al., 2004; Strasberg et al., 2009). There are many predictors of classified complications: procedure-specific complication grading, expanded classification, complications with a permanent disability, time horizon of complications, presentation of complications, and intraoperative vs postoperative complications (Dindo et al., 2004).

Clavien et al. introduced in 1992 a new approach to rank complications by severity based on the therapy used to treat the complications and differentiated three types of adverse outcomes after surgery (Clavien et al., 1992). After its routine use for more than 12 years, the grading system was revisited in 2004 (Dindo et al., 2004). A new classification of surgical complications based on therapy-oriented, 5-level severity grading was introduced. Complication classification in this method is based on the type of therapy needed to fix the complication (Clavien et al., 2009) (Table 3). Complications are categorized as minor at grade III or below and as major when the grade exceeds grade III.

Table 3 *Clavien-Dindo classification of surgical complications*

Grade I	Any deviation from the normal post-operative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions. Allowed therapeutic regimens are drugs such as antiemetics, antipyretics, analgesics, diuretics, electrolytes, and physiotherapy. Wound infections opened at the bedside are included	Minor complications
Grade II	Requiring pharmacological treatment with drugs other than for grade I complications. Blood transfusions and total parenteral nutrition are included	
Grade IIIa	Surgical, endoscopic, or radiological intervention that is not under general anaesthesia	
Grade IIIb	Surgical, endoscopic, or radiological Intervention that is under general anaesthesia	
Grade IVa	Life-threatening complication requiring intermediate care or intensive care unit management, single-organ dysfunction (including dialysis, brain haemorrhage, ischaemic stroke, and subarachnoidal bleeding)	Major complications
Grade IVb	Life-threatening complication requiring intermediate care or intensive care unit management, multi-organ dysfunction	
Grade V	Death	

2.14. COMPLICATION CLASSIFICATION BY TIME OF EVENT

The complications after BCS can also be classified by the time of the event. Immediate complications (≤24 h), which are also the most life-threatening, include large haematoma with active bleeding, venous thromboembolism (VTE) and pulmonary embolism (PE). Early complications (1–7 days after the operation) include seroma, most wound healing complications, and local haematoma, fat necrosis, and late complications (>7 days after the operation) include less common keloid/scar hypertrophy, dog ear, lymphoedema, and cutaneous nerve damage (Pollock et al., 2012).

2.15. POST-OPERATIVE COMPLICATIONS AFTER LBCS

The LBCS after MWL is associated with relatively high numbers of post-operative complications ranging from 28% to 78% (Kitzinger et al., 2013; Neaman et al., 2007; Poodt et al., 2016; van der Beek et al., 2011). Post-bariatric patients have been described as a high-risk surgical population. The most frequent complications described as a minor range from 27% to 56% of the overall complication rate and include delayed wound healing problems, wound dehiscence, suture extrusion, skin necrosis, seroma, local wound infection, and small haematoma (Dutot et al., 2018; Grieco et al., 2015; Poodt et al., 2016). The minor complication rate is significantly higher in combined multiple-procedure cases than in single-procedure cases (Coon et al., 2010). Major complications ranging from 7% to 21% include bleeding/haematoma requiring surgical revision, VTE and PE (Rosa et al., 2019a). Patients with post-operative complications had a significantly higher re-operation rate, longer hospital stay, and more dissatisfaction with BCS (Grieco et al., 2015) (Table 4).

2.15.1. Risk factors for complications

Variable risk factors have been described for the high incidence of post-operative complications after LBCS. Consistent pre-operative patient selection is a key factor in reducing complications after LBCS. Patients must be informed of the existence of risks. High pre-operative BMI, co-morbidities, and smoking are independent risk factors for the post-operative complications mentioned earlier in the text (see the Patients selection and information section).

2.15.1.1. Age and gender

Patients aged younger than 60 years had a significantly lower complication rate after BCS than patients aged 60 years or older (3.9% vs 5.3%; $p<.01$) (Winocour et al., 2015). The same study indicated that the male sex constituted the most significant pre-operative risk factor for complications, with a relative risk of 1.8 in multivariate regression. Another study demonstrated that the male gender was an independent risk factor for haematoma and seroma (Chong et al., 2012).

2.15.1.2. Weight loss method

Post-bariatric patients had been exhibited to have more complications after LBCS than those who lost weight by a non-surgical method (Breiting et al., 2011; Chetta et al., 2016; Froylich et al., 2015; Staalesen et al., 2012). BS may change patient metabolic outlines and eventually influence post-operative outcomes (Naghshineh et al., 2010). Based on a meta-analysis involving 1104 patients with preceding MWL, there is a 60–87% increased risk of having complications after BCS if a patient has previously received BS (Hasanbegovic et al., 2014).

A retrospective study of 222 patients showed more wound surgical complications after abdominoplasty and panniculectomy in post-bariatric patients than in non-bariatric patients (41% vs 22%; p<.01) (Greco et al., 2008). Another study analysed the complication rate of 190 patients who had undergone abdominoplasty after MWL by either BS (95 patients) or dieting (66 patients). The early complication rate was significantly higher (p=.0188) in post-bariatric patients (48%) than in patients without preceding BS (29%) (Staalesen et al., 2012).

2.15.1.3. Weight of resected tissue

The more skin and soft tissue are resected, the greater the risk of impaired wound healing and infections after BCS (Araco et al., 2012). Patients with a resected fat tissue ≥1000 grams had significantly more problems with post-operative wound healing than patients with resected fat <1000 grams (Constantine et al., 2014). There is a probability of 50% or more for wound healing problems when ≥4000 grams are removed (Steenackers et al., 2018). In the group of patients with complications, a mean of 3957 grams of tissue had been resected, compared with a mean of 1849 g in patients who did not develop complications (p=.0001) (Neaman et al., 2007).

2.15.1.4. Combined procedures

The complication rate is higher among patients who underwent multiple concomitant procedures (Saad et al., 2014; Winocour et al., 2015). The minor complication rate is predictably higher in concomitant procedures than in single-procedure cases (Coon et al., 2010).

2.15.1.5. Surgical management

Numerous surgical management techniques are available to decrease complications. Such management includes selective undermining (Neaman et al., 2013; Xiao and Ye, 2017), closed suction drains (Berjeaut et al., 2015;

Seretis et al., 2017), internal fixation techniques (Pollock et al., 2012), electrosurgical bipolar (Giordano et al., 2020), use of pressure dressing (Berjeaut et al., 2015; de Kerviler et al., 2009) and fibrin glue (Pilone et al., 2015). None of these has been found to be totally effective.

2.16. WOUND HEALING COMPLICATIONS AFTER LBCS

The incidence of wound healing complications after BCS in the MWL population varies in the literature from 8% to 61% (Greco et al., 2008; Kitzinger et al., 2013; Nemerofsky et al., 2006; Poodt et al., 2016). These complications include wound healing delays, suture extrusion, wound dehiscence, skin necrosis, and also necrosis around the umbilicus area. When wound healing problems are present, they endanger the aesthetic outcome and the final patient satisfaction. Usually, these minor wound healing complications could be managed in an outpatient clinic with primary local wound care being sufficient. Major dehiscence may require a planned re-operation.

Some clinical evidence has demonstrated that post-bariatric BCS patients experience similar complication rates as other high-risk groups, like cancer patients, transplant receivers, obese patients, and severe burn patients (Beecher et al., 2016; Deptuła et al., 2019; Mayhall, 2003). After BCS, MWL patients have a statistically significant growth risk of developing wound complications in the post-operative period than those with no previous MWL (Constantine et al., 2014). The reasons for abnormal wound healing are multifactorial: malnutrition, quality of skin due to poor skin elasticity, prolonged operation, and intraoperative hypothermia may all contribute to the pathogenesis (Agha-Mohammadi et al., 2008; Albino et al., 2009; Gusenoff et al., 2008; Kurz et al., 1996). Wound dehiscence and healing problems usually occur at the tightest point of abdominal incision closure due to impaired blood flow. The area darkens, and necrosis may occur following interruption of the closure, sometimes with the wound pulling apart.

BMI >30 kg/m^2, smoking, poorly controlled T2DM, haematoma, or seroma formation are also potential aetiological factors for wound dehiscence and tissue necrosis (Greco et al., 2008; Hunecke et al., 2019; Modarressi et al., 2013; Romano et al., 2019). Moreover, if patients are too active too soon after the operation, dehiscence may occur. Wound dehiscence can occur either immediately after surgery or later in the postoperative period. Treatment for dehiscence is most often conservative.

2.16.1. Formation of seromas

Seromas are the most frequent complication in many clinical series after LBCS (Ardehali et al., 2017; Neaman et al., 2007; Seretis et al., 2017). Seromas are reported to affect 5–40% of LBCS patients (Hunecke et al., 2019; Kim et al., 2006; Neaman et al., 2007; Stewart et al., 2006).

The heavy flap and extensive dissection from the pubis to xiphoid with an empty space of raw dissected soft tissue is freely filled with serous fluid. Seromas are usually self-limited. Seromas can be associated with other complications, including wound dehiscence, flap necrosis, and local infections, leading to repeated outpatient visits. Moreover, seroma creation can delay recovery time and the patient's return to normal daily routines. In some patients, seromas may be encapsulated, requiring further surgical treatment or conservative treatment (Seretis et al., 2017).

Previous studies have identified multiple risk factors for seroma formation: age, pre-operative BMI >30 kg/m^2, excess weight loss, and increased weight of excised skin (Kitzinger et al., 2013; Parvizi et al., 2015). Furthermore, T2DM, hypertension, and smoking have been found to increase the risk for seromas, acting through the disruption of microvascular lymphatic damage (Neaman et al., 2007). However, no evidence-based proof of a direct effect on seroma formation has emerged.

Surgical strategies, including progressive tension sutures (Jabbour et al., 2017; Macias et al., 2016; Pollock et al., 2012), Scarpa fascia preservation (Costa-Ferreira et al., 2010), different internal fixation techniques (Sforza et al., 2015) and use of adhesives or fibrin glue (Pilone et al., 2015; Toman et al., 2007), have been proposed to lower the seroma rate. Closed suction drains and compression garments are commonly used during the early postoperative period to facilitate the extrusion of seroma fluid from the operation area and allow the raw tissue to glue together (Anker et al., 2020; Khansa et al., 2018). Liposuction combined with abdominoplasty could elevate the risk for seromas (Kim et al., 2006; Najera et al., 2011).

2.16.2. Post-operative wound infections

Infections after BCS are relatively common, with an estimated incidence between 3% and 15% of operated patients (Hunecke et al., 2019; Neaman et al., 2007; Wiser et al., 2019). Post-operative infections can range from moderate local cellulitis that responds to a sequence of oral antibiotics to a raging infection that requires surgical debridement, intravenous antibiotics, and lengthy healing. Malnutrition (Agha-Mohammadi et al., 2008; Naghshineh et al., 2010), T2DM (Martin et al., 2016), method of weight loss (Greco et al., 2008), lifetime maximal BMI (Coon et al., 2009), high pre-operative BMI (de Kerviler et al., 2009) and smoking (Gravante et al., 2007) have been described as risk factors for post-operative wound infections after LBCS.

Data on the effectiveness of pre-operative antibiotics in preventing post-operative infections after BCS are contradictory (Ariyan et al., 2015). In some studies, pre-operative antibiotic prophylaxis seems to lower the risk for wound infections (Swedenhammar et al., 2018; Wiser et al., 2019).

2.17. HAEMATOMA AND BLEEDING

The incidence of post-operative haematoma complications has been reported to range from 2% to 20% (Guest et al., 2017; Hensel et al., 2001; Hunecke et al., 2019). Usually, post-operative haematomas and bleeding manifest in the immediate (within 24 hours) or early (1 to 7 days) post-operative period. The clinical appearance of a haematoma depends on its volume. In small haematomas, conservative management is the safest way to deal with this complication. In case of vast bleeding, haematoma manifests with swelling and localized pain and can consequently result in haemodynamic instability and hypovolaemic shock. Frequently, these complications require immediate surgical evacuations and blood transfusion (Arthurs et al., 2007; Masoomi et al., 2015). The prevalent risk factors for haematoma and bleeding are high pre-operative BMI, female gender, chronic anaemia, T2DM, coronary artery disease, hypertension, unsuccessful haemostasis during operation, and coagulopathies (Masoomi et al., 2015; Rogliani et al., 2006; Vidal et al., 2017).

2.18. VENOUS THROMBOEMBOLISM AND PULMONARY EMBOLISM

VTE and PE are important causes of morbidity and mortality following body BCS (Colwell et al., 2008; Nemerofsky et al., 2006). Fortunately, the incidence of VTE and PE is reported to be as low as 0.2-2.9% after BCS (Pannucci, 2017; Shermak et al., 2007; Wes et al., 2015). Patients undergoing abdominoplasty are at higher risk for VTE or PE if their pre-operative BMI is ≥30 kg/m^2, older than 60 years, or abdominoplasty is combined with another intra-abdominal procedure (Hatef et al., 2010; Wes et al., 2015).

Plastic surgeons have no consensus on appropriate VTE prophylaxis after BCS. However, the presence of VTE prophylaxis may be acceptable (Marangi et al., 2016; Pannucci, 2017; Shermak et al., 2007). Pre-operative chemoprophylaxis in patients undergoing abdominoplasty can be applied without increasing bleeding complications or overall complication rate (Campbell et al., 2014).

Death after BCS has rarely been reported in the literature, with an incidence of only 0.04–0.16% (Christman, 1986; Hunecke et al., 2019; Vidal et al., 2017). Most cases of mortality were associated with massive pulmonary embolism.

2.19. RE-OPERATION

The re-operation rate due to post-operative complications after BCS varies from 0.30% to 13.4%. Re-operations include revision of skin and fat, necrosis, wound dehiscence, abscess, seroma, and haematoma evacuation (Chetta et al., 2016; de Kerviler et al., 2009; Froylich et al., 2015).

Table 4 *Previous studies of post-operative complications and risk factors after LBCS with more than 100 patients include*

Ref.	n*	Procedure	Signif. risk factors for complications	Complication rate	Complications (n)
Poodt et al. 2016	100	Lower body lift	BMI, Smoking	78 %	Wound dehiscence (61), Infection (44), Seroma (32), Skin Necrosis (13), Haematoma (8), PE (1)
Greco et al. 2008	222	Abdominoplasty/ panniculectomy	ASA class	34 %	Wound Healing disturbance (24), Wound infection (27), Hematoma (13), Seroma (33)
Hunecke et al. 2019	121	Abdominoplasty	T2DM, cardiovascular diseases	18.2 %	Wound infection (4), Tissue necrosis (2), hematomas (4), Seroma (9), Severe internal complication (1)
Arthur et al. 2007	126	Panniculectomy	PRE-operative BMI	40 %	Seroma (22), Hematoma (16), Surgical site infection (22), Wound breakdown (14), Transfusion (8)
Staalesen et al. 2012	161	Abdominoplasty	N/A	Bariatric 48 %, non-Bariatric 29 %	Wound dehiscence (28), Skin necrosis (7), seroma+ hematoma (38), local infection (28), fat necrosis (5), fistulation (5), Ulcus (1), DVT (1)
de Kerviler et al. 2009	104	Abdominoplasty/ beltlipectomy	Total tissue resection weight, BMI	26.9 %	Wound dehiscence (21), Seroma (8),
Momeni et al. 2008	139	Abdominoplasty	BMI over 30 kg/m2	40.3 %	Seroma (29), Delayed wound healing (10), Skin necrosis (3), Wound dehiscence (1), Umbilical necrosis (3), Hematoma (4)
Parvizi et al. 2015	205	Abdominoplasty/ Lower body lift	BMI >30kg /m2, smoking, Amount of removing tissue,	51.7 %	Infection (8), Seroma (10), Hematoma (15), Wound healing problems (19), Wound dehiscence (13), Sutural fistula (11) Skin edge or fat necrosis (15), Anaemia (12), PE (3)

**Number of patients*

2.20. SARCOPENIC OBESITY

Skeletal muscle contains approximately 40 % of total body weight and comprises 50-75% of all body proteins (Frontera et al., 2015; Mukund et al., 2020). Skeletal muscles play a crucial role in whole-body metabolism. The most obvious metabolic explanation for muscle decline is an imbalance between protein catabolism and anabolism (Xiao 2018; Mukund et al., 2020). Many factors regulate muscle function, including nutrition, genes, and intensity of exercise (Chikani et al., 2014; Sakuma et al., 2017). In addition, many hormones, including growth hormone, thyroid hormones, androgens, estrogen and glucocorticoids, exert a significant effect on muscle growth and function. The muscles modulate blood glucose levels by insulin-mediated glucose uptake, and when this is impaired, insulin resistance can lead to type 2 diabetes (Parikh et al., 2021).

Sarcopenia is defined as a loss of muscle mass that leads to muscle weakness, limited mobility, and increased susceptibility to injury (Edwards et al., 2015). Primary sarcopenia is caused by ageing itself, and secondary sarcopenia is caused by immobility or physical inactivity, a disease such as advanced organ failure, malignant disease, neurodegenerative or endocrine disease and poor nutrition (Lafortuna et al., 2014). Weight loss is a major aetiological factor for sarcopenia (Cruz-Jentoft et al., 2019). Sarcopenia is strongly associated with weakness, physical disability, hospitalization, osteoporosis, osteoarthritis, and even mortality (Borodulin et al., 2019; Dhillon et al., 2017; Woo, 2017).

Baumgartner first defined sarcopenic obesity in 2000 (Baumgartner 2000). Obesity is associated not only with medical disorders but also with disorders of the musculoskeletal system that worsen over time, as obese people tend to avoid regular weight-bearing exercises (Alba et al., 2019; Lafortuna et al., 2014). People with overweight have poor muscle strength, with an inverse relationship between adiposity, muscle lipid content, and reduced muscle function (Alba et al., 2019; Lafortuna et al., 2014). Obesity worsens sarcopenia, and sarcopenia is often associated with an increase in adipose tissue in general in the muscle, with this disease being defined as sarcopenic obesity (Godziuk et al., 2018; King et al., 2016). The prevalence of sarcopenic obesity varies from 4% to 12% (Davison et al., 2002; Stenholm et al., 2008; Zoico et al., 2004).

Sarcopenia and obesity may have a common inflammatory pathway (Zamboni et al., 2008). Adipocytes directly and infiltrating macrophages producing pro-inflammatory cytokines and adipokines, which control the inflammatory reaction (Calabro et al., 2008). Increased inflammation, in turn, may lead to catabolism and decreased muscle mass and muscle strength (Schaap et al., 2013).

Sarcopenia or obesity increases the risk of all-cause mortality, and the existence of both is assumed to synergistically increase this risk (Zhang et al., 2019). In addition to the cardiovascular and metabolic risks incurred with obesity, there are well-established connections between obesity and impaired skeletal muscle quality, poor physical performance, and a higher risk of functional decrease, suggesting that bariatric surgery-induced weight loss could potentially lead to improvements in these parameters (Lafortuna et al., 2014; Schaap et al., 2013).

Weight loss is an additional and significant aetiological factor for sarcopenia (Cruz-Jentoft et al., 2019). However, despite the extreme loss of fat mass after BS, there is also a significant loss of muscle mass, potentially having a negative effect on muscle strength and physical performance (Carey et al., 2006; Stegen et al., 2011; Zalesin et al., 2010). After a diet-induced weight loss of 8–10%, the reduction in muscle mass could be 2–10% in morbidly obese persons (Cava et al., 2017). Another study measured musculus vastus medialis thickness after matched weight loss accomplished by either a hypocaloric diet or gastric banding operation and found a more significant reduction in musculus vastus medialis thickness in the bariatric surgery group (Teichtahl et al., 2016).

3 AIMS OF THE STUDY

Overall, the aim of this study was to evaluate patients who have redundant excess skin around their lower body due to massive weight loss.

Specific aims were as follows:

I To examine the current incidence of LBCS in post-bariatric patients in Finland between 1998 and 2016.

II To investigate the possible effect of LBCS on pregnancy and delivery for mother and child.

III To assess the frequency of post-operative complications after LBCS.

IV To evaluate muscle strength of patients who have excess redundant skin around the lower body due to massive weight loss and who meet the criteria for BCS.

4 PATIENTS AND METHODS

4.1. DATA SOURCES

The studies for this thesis were carried out at Helsinki University Hospital, Finland.

Studies I and II were national retrospective register linkage studies. Permission to use the register information on bariatric and LBCS patients in scientific research was obtained from the Finnish Institute of Health and Welfare (THL), and Statistics Finland after the data protection authority was consulted. The ICD-10 classification of diseases and classification of surgical procedure codes were applied. All hospitals had sent data on their surgical procedures to the National Hospital Discharge Register (NHDR), maintained by the Finnish Government, and collects data on the activities of health centres, hospitals, and other institutions providing inpatient care for the purposes of statistics, research, and planning. The coverage of the registry has been nearly 100% from 1987 onwards (Sund, 2012). The register includes basic data on the service provider, patient, and treatment received by the patient, e.g., diagnoses, procedures, interventions, and discharge from care. The data includes no freehand text from patient files, such as indications or decisions for a specific type of operation or procedure.

Data on death and cause of death after operations came from the Cause of Death Register, maintained by Statistics Finland (Studies I and II). The main and other causes of death were recorded in ICD-10 codes. The Medical Birth Register was queried for pregnancies and deliveries of participating women (Study II). Information from the different registers was merged through record linkages using personal identification numbers (PICs). All citizens and permanent residents in Finland have a unique PIC introduced in 1964–1967. The PIC used in all main registers in Finland allows reliable deterministic record linkage.

In Study III, the LBCS patients were operated on at the Department of Plastic Surgery, Helsinki University Hospital, Töölö Unit between January 2009 and December 2015. The patients were identified from the hospital electronic database Centricity Opera® (GE Healthcare, USA). Patients with MWL through either BS or lifestyle changes were included. Patients whose indication for abdominoplasty was post-pregnancy were excluded.

In Study IV, participants were recruited during scheduled outpatient clinic visits at the Töölö Hospital Plastic Surgery Department during 2017-2018.

4.2. PATIENTS

4.2.1. Study I

This study comprised 7703 patients who received BS in Finland between 1 January 1998 and 31 December 2016.

Bariatric surgery

The bariatric operations were identified by surgical procedure codes. The codes included open and laparoscopic gastric bypass, sleeve gastrectomy, gastric banding, and biliopancreatic diversion with or without duodenal switch defined as in (Bockelman et al., 2017): JDF00-01, JDF10-11, JDF20-21, JDF96-98, JFD00, JFD03-04, JFD96. Only patients 18 years of age or older at the time of the bariatric procedure were included.

LBCS

This study covered the two most common lower body contouring procedures, abdominoplasty (QBJ30) and body lift (QBJ05) after BS. Patients with LBCS without previous BS were excluded.

Other contouring procedures after bariatric surgery

Data on all other plastic surgery procedures for redundant skin besides abdominoplasty and body lift, including liposuction, brachioplasty, thigh lift, and breast reshaping after BS, were collected.

Education levels

Information on individuals' educational level was linked to the Register on Education, kept by Statistics Finland. In population registers, education is recorded as the last degree taken by the respondent. The linkage was done by PIC. The Classification on Completed Education and Degrees was used to divide the educational level into three broad categories: high, intermediate, and low education. High education included those with technical college, university, postgraduate, and higher vocational degrees with 14/15 or more years of education. Intermediate education included those with secondary education and vocational training with 10-14/15 years of education, and low education included those with primary education and those whose education status was unknown with ≤nine years of education.

Hospital district

Finland is divided into 21 public hospital districts that provide specialized medical care. Each hospital district includes a central hospital and other smaller regional and local hospitals. There are also five university hospitals that provide highly specialized medical care. Each of the 21 hospital districts belongs to one university hospital area. University hospitals and central hospitals are responsible for the most demanding medical operations. In Finland, the public health care system covers LBCS after MWL. All other contouring procedures must be procured in the private sector unless the deformities cause significant daily functional health problems.

4.2.2. Study II

Ninety-two women who had undergone LBCS before pregnancy and delivery were identified out of 1 028 503 total pregnancies and deliveries in Finland in 1999–2016.

LBCS

The lower body contouring operations were identified based on surgical procedure codes. Codes indicating lower body contouring procedures were abdominoplasty (QBJ30), body lift (QBJ05), and other aesthetic corrections of the skin of the trunk (QBJ99).

Bariatric and non-bariatric groups

The data were further analyzed by dividing patients into two groups depending on whether there had been a bariatric procedure before the LBCS. Altogether, 26 women (28.3%) had a bariatric procedure, and 66 (71.7%) had not. The year and type of BS were collected. Bariatric procedures were identified from surgical procedure codes for sleeve gastrectomy (SG) and gastric bypass (RYGB). The bariatric and non-bariatric groups were compared with all pregnancies and deliveries in Finland during the study period.

Medical Birth Register

Entry fields included all fertile women aged between 18 and 54 years. Recorded were information on women's age at onset of pregnancy, parity, length of pregnancy, termination of pregnancy, miscarriage, preterm birth (<37 weeks), mode of delivery, and low birth weight (<2500 g). Visits to maternity and hospital clinics during the pregnancy were noted. Pre-delivery diagnoses were also reported. Self-reported body mass index (BMI) in early pregnancy has been recorded in the Medical Birth Register since 2004. BMI was divided into five classes: <18.5 kg/m^2 (underweight), 18.5–24.9 kg/m^2 (normal weight), 25–29.9 kg/m^2 (pre-obesity), 30–34.9 kg/m^2 (obesity, class I), and ≥ 35 kg/m^2 (obesity class II, III). The time between LBCS and pregnancy was also recorded.

4.2.3. Study III

The specific inclusion criteria resulted in 158 patients who had to precede MWL through either BS or lifestyle changes following abdominoplasty or body lift from 1 January 2009 to 31 December 2015. Patients whose indication for abdominoplasty was post-pregnancy were excluded.

Computerized medical records

Computerized medical records were reviewed in detail, and data were collected on the following: age, gender, co-morbidities, such as arterial hypertension and T2DM, dyslipidaemia, former abdominal surgery, smoking (current smoker, former smoker, non-smoker), the highest lifetime weight and BMI, and weight loss method (surgical or non-surgical).

LBCS

The LBCS-specific variables comprised age, weight and BMI on the day of LBCS, the specific procedure, and the operative time for body contouring. Also noted were the haemoglobin rate before and after surgery, duration of hospital stays, institutional discharge, and any complications.

Complications

The documentation of complications consisted of wound infections, wound dehiscence, seroma, haematoma or wound bleeding, deep-tissue infection, skin necrosis, deep-vein thrombosis, embolism, and sepsis. Complications were grouped into four categories based on their occurrence: immediate complications occurred 0–24 h after the body contouring procedure, early complications occurred 1–7 days after surgery, late complications occurring 8–30 days after the procedure, and complications requiring re-admission. Finally, all complications were divided into five grades according to the Clavien–Dindo classification.

4.2.4. Study IV

The study protocol was approved by the Ethics Committee of the Hospital District of Helsinki and Uusimaa (HUS/2558/2016). Participants were informed about the details of the study, and they signed written informed consent.

During the study period, 23 patients gave written informed consent to participate in the study. They were admitted to plastic surgery due to MWL and redundant loose skin. Computerized medical records were reviewed in detail, and data extracted for each patient included the following: age, gender, co-morbidities (e.g., arterial hypertension, diabetes, and dyslipidaemia), former abdominal surgery, smoking status (current, former, non-smoker), the highest lifetime weight, highest BMI, weight loss method (surgical or non-surgical), current weight, and current BMI.

Indication for LBCS

All participants had MWL through either BS or lifestyle changes and had functional and/or physical problems with redundant skin. The prerequisites for BCS after MWL were BMI ≤30 kg/m^2, stabilized weight for at least one year, and non-smoker status. After examination by a plastic surgeon, patients were informed about the operation and placed in the surgical queue. At the end of the outpatient clinic visit, the plastic surgeon asked for the patient's consent to participate upon disclosing details of the study and providing written information on the protocol. If they were willing to participate, the patient signed a written informed consent.

Muscle strength test

Participants performed the tests individually. A physical therapist administered all tests in Töölö Hospital, Helsinki, Finland. Testing occurred between May 2017 and December 2018. The physiotherapist explained and demonstrated the test movements to the subject before each test. No practice trials were allowed.

All three fitness tests have age- and gender-related reference values. The tests have been well-established and have been widely used in population surveys and clinical studies (Borodulin et al., 2019: Lundqvist 2016). These results provided an absolute value as well as a norm-referenced value. The dynamic muscle endurance of the trunk flexors and the lower extremities was evaluated by the dynamic muscle strength of the body and the squat test. The maximal isometric hand grip strength of the dominant hand was measured with a dynamometer.

Hand grip strength test

The hand grip strength was measured with a JAMAR® hydraulic hand dynamometer, which quantifies isometric force in kilograms from the dominant hand using a validated procedure (Roberts et al., 2011) (Figure 6). The size of the grip handle was adjusted according to the size of the subject's hand. The width of the grip was appropriate when the middle joint of the index finger was at a 90° angle. The participant sat straight in a chair, with their feet slightly apart on the floor. They held the dynamometer with the wrist in a neutral position (i.e., in slight dorsal flexion) and the elbow at 90°. Participants were asked to grip the handle as hard as possible for 3–5 seconds. During this time, the subjects were urged to do their best. The second measurement was conducted 30 seconds later. The best result in kilograms was registered. If the two results differed by more than 10%, a third attempt was made.

Figure 6 *Position of participants during the hand grip strength test*

Dynamic muscle strength of body test

Participants lay supine on the exercise mat with knees flexed at 90° (Figures 7). Participants were instructed to keep their ankles and knees together, and the study physiotherapist supported the ankles with her hands to keep the feet on the mat throughout the sit-up. Five repetitions of sit-ups were performed in three different hand positions, i.e., levels of difficulty. The first five sit-ups were performed with the fingertips of both hands reaching the knee from a straight lying position while keeping the arms straight and the palms resting on the thighs. The second five sit-ups were performed with arms folded over the chest. Participants had to reach their thighs with both elbows. The last five sit-ups were performed with fingertips of each hand around the earlobes. Participants had to reach their thighs with both elbows. No rest was provided between each level, and there was one test trial at each performance level. Between each sit-up, the back of the head and the elbows had to touch the mat.

Figure 7 *Dynamic muscle strength of body test.*

The squat test

The subject was standing in a crouch position with feet placed apart. The shoulder, hips, knees, and ankles were in a straight line (Figures 8). The subject squatted, flexing his legs with his back straight, with the fingertips touching the floor at the outer area of the foot. From this position, a participant raised themselves to the starting position. The number of squats performed in 30 seconds was recorded. Only complete and correct performance counted, i.e., the fingers touched the floor, the thighs were horizontal, and the knees and back were extended.

Figure 8 *The squat test*

Reference values

The reference values for hand grip strength were based on measurements of a sample of the adult population in the FinHealth 2017 Study (Borodulin et al., 2019; Koponen et al., 2018), (Table 6). Approximately 20% of the population of each age and gender group belongs to each of the five fitness classes (1: poor, 2: fair, 3: average, 4: good, 5: excellent).

Table 6 *Reference values for the hand grip strength test according to age and sex*

Age / Fitness level	18–29 years		30–39 years		40–49 years		50–59 years		60–69 years		70–79 years		80 +	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
1 Poor level	<43	<27	<48	<29	<46	<30	<43	<27	<38	<23	<33	<20	<24	<15
2 Fair level	43–50	27–29	48–52	29–31	46–51	30–32	43–47	27–29	38–43	23–26	33–37	20–22	24–28	15–18
3 Avarange level	51–55	30–33	53–56	32–34	52–54	33–35	48–52	30–32	44–47	27–28	38–41	23–25	29–33	19–21
4 Good level	56–60	34–36	57–61	35–38	55–60	36–38	53–58	33–35	48–52	29–31	42–46	26–28	34–39	22–23
5 Exellent level	≥61	≥37	≥62	≥39	≥61	≥39	≥59	≥36	≥53	≥32	≥47	≥29	≥40	≥24

The reference value for the dynamic muscle strength of the body test was based on the Fitness for Health: The ALPHA-FIT Test Battery for Adults Aged 18-69 Years (Suni et al., 2009). The maximum number of sit-ups was 15. Due to the skewed distribution of the test results, the fitness categories were based on percentages of certain performance levels from two Finnish population studies conducted by the UKK Institute (UKK-institute, 2014) (Table 7).

Table 7 *Reference values for the dynamic muscle strength of body test. Due to skewed distributions of the test results, the fitness categories are based on percentages of certain performance levels from two Finnish population studies conducted by the UKK Institute*

Fitness level	30-39 years		40-49 years		50-59 years		60-69 years	
	Men	women	Men	Women	Men	Women	Men	Women
Level 1, low fit 0-5 repetitions	2 %	10%	8%	15%	18%	38%	27%	47%
Level 2, mid-fit 6-14 repetitions	5 %	10%	11%	20%	14%	14%	15%	22%
Level 3 high-fit 15 repetitions	93%	80%	81%	65%	68%	38%	58%	31%
	100%		100%		100%		100%	

The reference values for the squat test were based on the Basics of Fitness Testing Report (Kuntotestauksen perusteet), which counts the number of squats in 30 seconds. Each age and gender group belongs to one of five fitness classes (1: poor, 2: fair, 3: average, 4: good, 5: excellent) (Table 8).

Table ***8*** *Reference values for the squat test, in which the number of squats performed in 30 seconds is recorded*

Age / Fitness level	20–30 years		30–39 years		40–49 years		50–59 years		60–65 years	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
1 Poor level	≤18	≤14	≤15	≤12	≤13	≤10	≤10	≤7	≤5	≤6
2 Fair level	19–23	15–18	16–19	13–16	14–17	11–14	11–13	8–10	6–10	7–9
3 Avarange level	24–28	19–22	20–23	17–21	18–21	15–18	14–17	11–14	11–14	10–12
4 Good level	29–32	23–26	24–28	21–23	22–23	19–21	18–20	15–18	15–18	13–15
5 Exellent level	≥33	≥27	≥29	≥24	≥24	≥22	≥21	≥19	≥19	≥16

5 STATISTICAL METHODS AND ANALYSES

In Study I, differences between BS patients with and without subsequent post-bariatric LBCS were tested by using the Chi-square test, the test of relative proportion, and t-test, as appropriate. All analyses were conducted using SAS version 9.3 (SAS Institute, USA). Survival curves were constructed according to the Kaplan-Meier method and compared with the log-rank test.

In Study II, differences between BS patients with and without subsequent post-bariatric LBCS were tested using the Chi-square test, the test of relative proportion, and the t-test, as appropriate. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for dichotomous variables, and weighted mean differences (WMDs) were calculated for continuous variables. All analyses were conducted using SAS, version 9.3. Groups were compared with each other and with all deliveries during the study period.

In Study III, statistical analyses were conducted using NCSS 2007 (NCSS Statistical Software, Kaysville, UT, USA) and SPSS Statistics, version 19.0 (IBM Corporation, New York, NY, USA). P-values of less than 0.05 were considered statistically significant. Comparisons between bariatric and non-bariatric groups were made using the Chi-square test, while continuous variables were analysed using Student's t-test and Mann-Whitney U-test. Chi-square test was applied to examine categorized risk factors, including gender, method of weight loss, diabetes, arterial hypertension, dyslipidaemia, former abdominal surgery, and smoking. Numeric risk factors, including age, the highest lifetime weight and BMI, weight and BMI on the body contouring surgery day, and operative time for body contouring, were analysed with the Mann-Whitney U-test. A matched-pairs test was used to analyse further the effect of the weight loss method on the rate of complications. Patients were stratified according to the weight loss method and were matched for age ±5 years and gender. McNemar´s test was used to examine the paired nominal data, and statistically significant p-values denoted differences between the cohorts.

In Study IV, all three fitness tests have age- and gender-related reference values. These results provided an absolute value and a norm-referenced value.

6 RESULTS

6.1. STUDY I

Patients and bariatric procedures

A total of 7703 patients (5529 women, 72%; 2174 men, 28%) underwent BS in Finland during 1998–2016. Their mean age was 47.4 years (Table 9).

The two most common bariatric procedures were gastric bypass (n=5687, 73.8%) and sleeve gastrectomy (n=1992, 25.9%). Jejunoileal bypass was performed on 19 patients (0.2%), duodenoileal bypass with a biliopancreatic diversion on three patients (0.04%) patients, and another intestinal bypass operation on two patients (0.03%).

Table 9 *Demographic and operation data for all BS patients (n=7703) in Finland during 1998-2016*

	All Bariatric surgery patients
n	7703
Mean Age (SD)	47.4 (10.3)
Men	2174 (28%)
Women	5529 (72%)
Sleeve gastrectomy	1992 (25.9%)
Gastric bypass	5687 (73.8%)
Jejunoileal bypass	19 (0.2%)
Duodenoileal bypass with biliopancreatic diversion	3 (0.04%)
Another intestinal bypass operation	2 (0.03%)

LBCS

Altogether, 1089 patients (14.1%) of all patients (n=7703) had undergone LBCS after BS in Finland during 1998-2016. Abdominoplasty was performed for 970 patients (89%) and body lift for 129 patients (11%). There were 184 men (16.9%) and 905 women (83.1%); thus, the gender ratio was 1:4.9. The mean age in this group was 44.9 years. The patients who had subsequent LBCS after BS were younger (44.9 vs 47.8 years, $p<.001$) and only rarely had sleeve gastrectomy ($p<0.001$) compared with patients without preceding LBCS (Table 10). A notable rise occurred in both bariatric and subsequent LBCS operations during the study period in Finland (Figures 9 and 10).

Table 10 *Demographic characteristics of post-bariatric patients with or without LBCS in Finland in 1998-2016. The p-values denote significant differences between two groups*

	LBCS after bariatric procedure	No LBCS after bariatric procedure	p-value
n (%)	1089 (14.1%)	6614 (85.9%)	
Mean Age (SD)	44.9 (9.7)	47.8 (10.3)	< .001
Women Men	905 (83.1%) 184 (16.9%)	4624 (70%) 1990 (30)	< .001
Sleeve gastrectomy Gastric bypass Jejunoileal bypass Duodenoileal bypass with biliopancreatic diversion Another intestinal bypass operation	215 (19.7%) 874 (80.3%) 0 0 0 0	1777 (26.9%) 4813 (72.8%) 19 (0.29%) 3 (0.055) 2 (0.03%)	 < .001
Abdominoplasty Body lift	970 (89%) 129 (11%)		

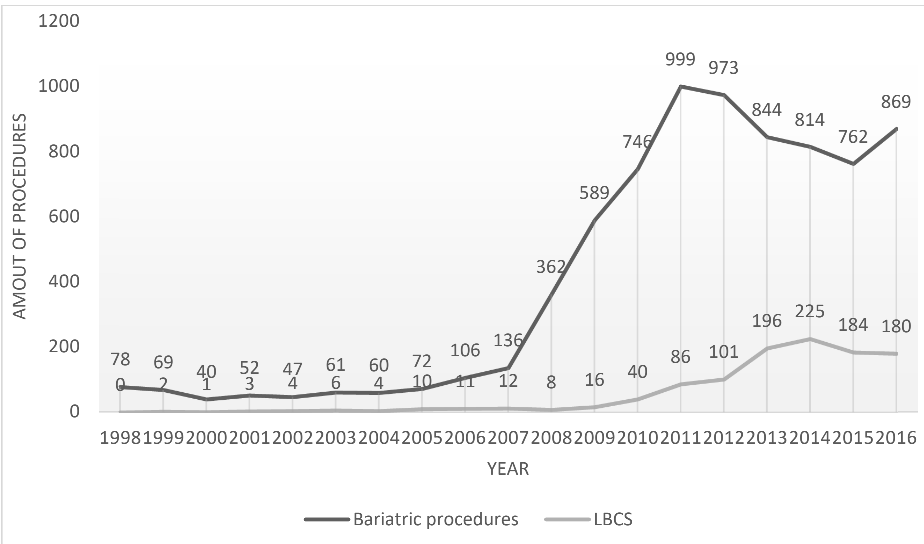

Figure 9 *The numbers of BS and post bariatric LBCS during 1998-2016*

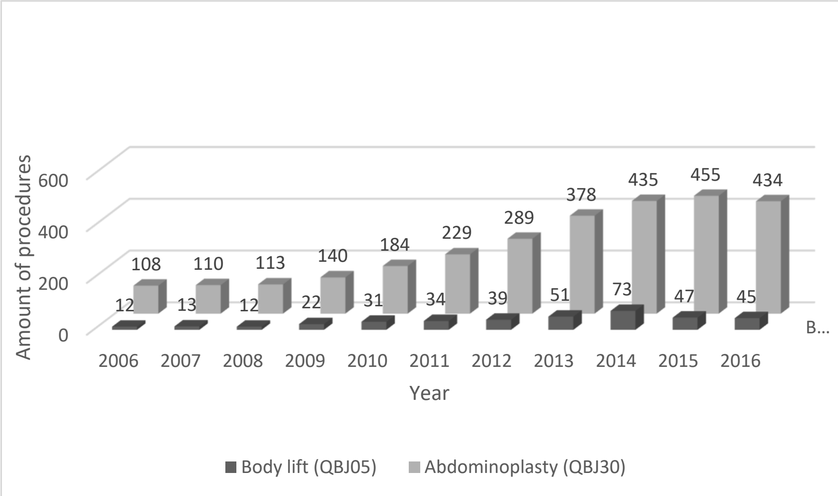

Figure 10 *Numbers of body lift and abdominoplasty procedures per year during 2006-2016 in Finland*

The latency between bariatric surgery and LBCS

The operation probability was stratified by the latency between BS and LBCS for bariatric patients according to abdominoplasty and body lift operations. The latency between BS and LBCS ranged from 5 months to 14 years, with a median latency of 31 months. In approximately the fifth year post-BS, the growth reaches a plateau (Figure 10).

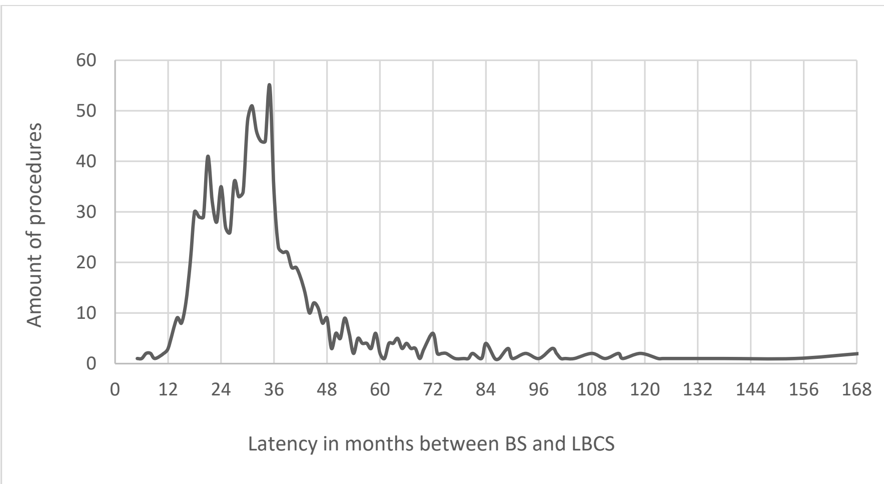

Figure 10 *Latency in years between bariatric surgery and LBCS in Finland during 1998-2016. The numbers include abdominoplasty (n=970) and body lift (n=129) procedures.*

The correlation coefficient for bariatric and post-bariatric procedures yearly is r = 0.683. However, the correlation coefficient is even stronger with a two-year latency between bariatric and post-bariatric operations (r = 0.927) (Figure 11).

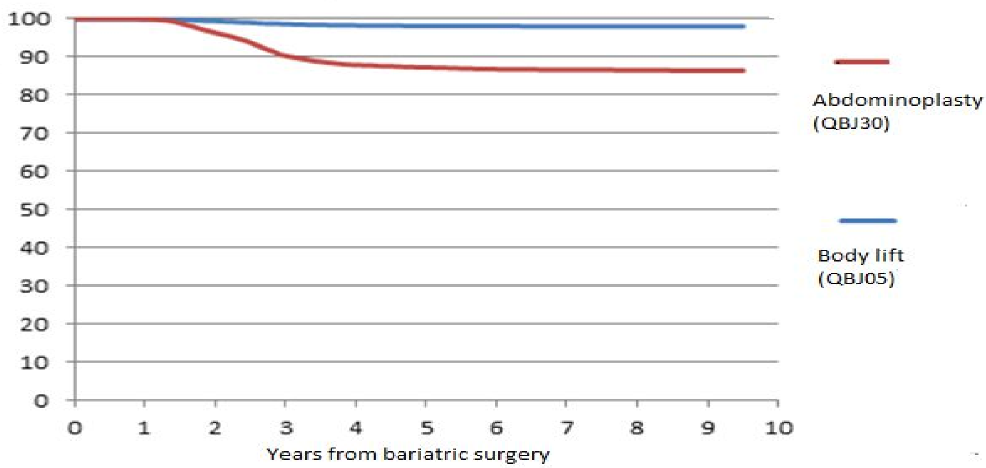

Figure 11 *Time in years from BS to LBCS (either abdominoplasty or body lift). Kaplan-Meier ($p < 0.001$, log-rank test) curves illustrate cumulative LBCS-free survival rates among patients who underwent BS.*

National distribution

Bariatric surgery

Most bariatric procedures (n=6901, 89.6%) were performed in public hospitals, with only 802 (10.4%) carried out in private hospitals. Altogether, 4018 bariatric procedures (52.2%) were done in the five university hospitals, and the rest in central or local hospitals (Figure 12). The numbers of BS ranged from 28 to 1804 per hospital district during 1998–2016 in Finland.

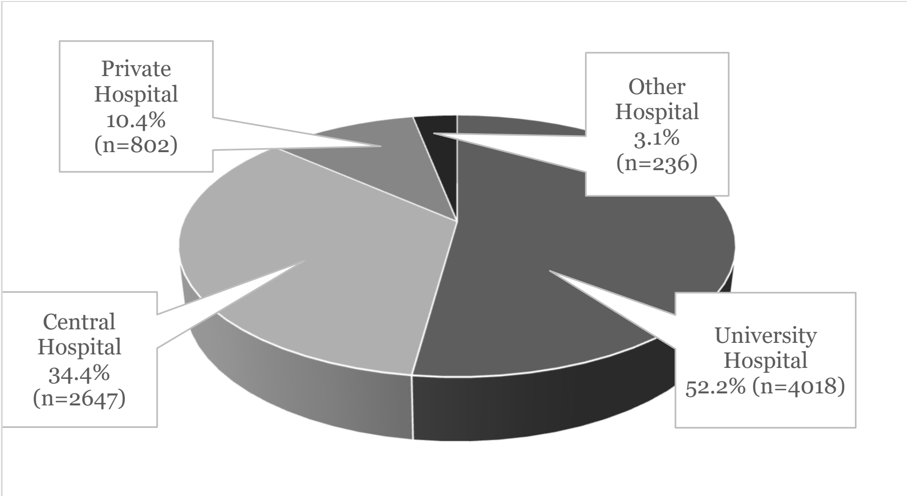

Figure 12 *The distribution of BS between public and private sectors. Total of 7703 (100%) patients who underwent BS in Finland during 1998–2016*

Lower body contouring surgery

Most of the LBCS (n=1060, 97.3%) were done in public hospitals, with only 2.7% (n=29) performed in private hospitals. LBCS operations ranged from 5 to 215 per hospital district, and 449 (41%) of all 1089 lower body contouring operations were done in the five university hospitals. The vast majority (n=835, 78.8%) of all public LBCS were carried out in the five university hospitals or the five hospital districts with larger volume central hospitals (Figure 13). The share of LBCS was greater than 20%, compared with the national mean of 14.1%, in only three hospital districts.

Altogether, 16 of the 21 hospital districts had less than 50 LBCS performed over the entire study period. The number of operations in the central or local hospitals ranged from 2 to 39. A total of 225 (21.2%) of all LBCS operations were performed in smaller hospital districts.

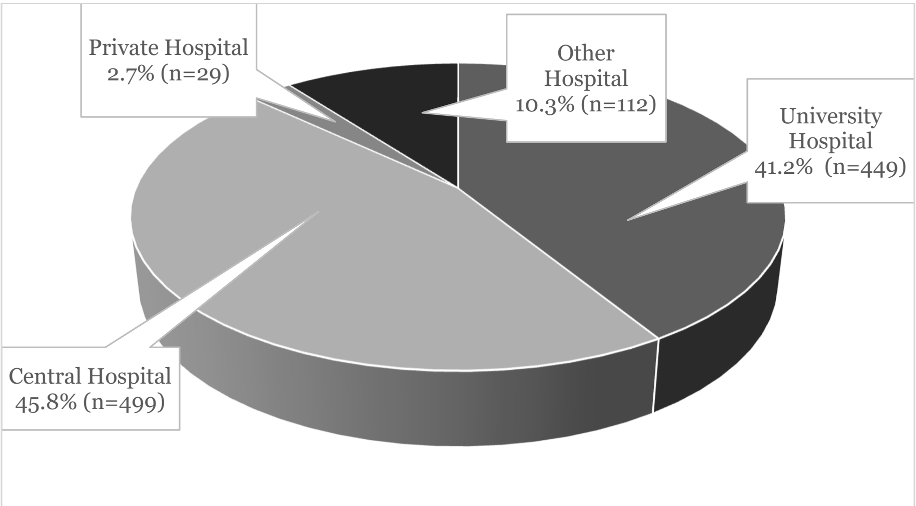

Figure 13 *The distribution of LBCS between public and private sectors. Altogether 1089 (100%) patients undergone LBCS after BS in Finland during 1998-2016*

Other contouring surgery after bariatric surgery

The most common contouring procedure was reduction mammaplasty with areola transposition or with transplantation was carried out in 319 patients (50.1%). The second most common contouring procedure was liposuction of the trunk (n=94, 14.8%) (Table 11). Altogether, 377 patients (59.2%) had undergone LBCS and some other contouring procedure after BS, and 260 patients (40.8%) had some other body contouring surgery after BS, but no LBCS (Table 11 and 12).

Table 11 *Other contouring procedures after BS with or without LBCS during 1998-2016 in Finland*

	n. (%) of all (7703) Bariatric patients	Percent of all other body contouring surgery, with or without LBCS (n= 637)
n (%)	637 (8.3 %)	100 %
Liposuction of trunk	94 (1.2 %)	14.8 %
Excision of loose skin or fold of skin from the trunk	40 (0.5 %)	6.3 %
Liposuction of upper limb	14 (0.2 %)	2.2 %
Correction of loose or redundant skin of the upper limb	29 (0.4 %)	6.3 %
Excision of loose skin or fold of skin from upper limb	11 (0.1 %)	
Liposuction in lower extremity	35 (0.5 %)	5.5 %
Correction of loose or redundant skin of the lower extremity	37 (0.5 %)	7.4 %
Excision of loose skin or fold of skin from lower limb	10 (0.1 %)	
Liposuction of breast	7 (0.1 %)	1.1 %
Reduction mammoplasty with transposition of the areola	297 (3.9 %)	50.1 %
Reduction mammoplasty with transplantation of areola	22 (0.3 %)	
Augmentation mammoplasty	1 (0.01 %)	0.2 %
Augmentation of breast using prosthesis.	5 (0.1 5 %)	0.8 %
Mastopexy	35 (0.5 %)	5.5 %

Table 12 *Demographic characteristics of patients (n=637) who underwent body contouring surgery after BS with or without LBCS. P-values denote the correlation between BS with and without LBCS.*

	LBCS+ other contouring procedure (%)	Other contouring procedures without LBCS	p-value
altogether 637 (100 %)	377 (59.2 %)	260 (40.8 %)	
Liposuction of trunk	79 (84.0 %)	15 (16.0 %)	<0.001
Excision of loose skin or fold of skin from the trunk	15 (37.5 %)	25 (62.5 %)	<0.001
Liposuction of upper limb	10 (71.4 %)	4 (28.6 %)	<0.001
Correction of loose or redundant skin of the upper limb	21 (72.4 %)	8 (27.6 %)	<0.001
Excision of loose skin or fold of skin from upper limb	8 (72.7 %)	3 (27.2 %)	<0.001
Liposuction in lower extremity	27 (77.1 %)	8 (22.9 %)	<0.001
Correction of loose or redundant skin of the lower extremity	33 (89.2 %)	4 (10.8 %)	<0.001
Excision of loose skin or fold of skin from lower limb	7 (70.0 %)	3 (30.0 %)	<0.001
Liposuction of breast	2 (28.6 %)	5 (71.4 %)	0.261
Reduction mammoplasty with transposition of the areola	137 (46.1 %)	160 (53.9 %)	<0.001
Reduction mammoplasty with transplantation of areola	8 (36.4 %)	14 (63.6 %)	0.008
Augmentation mammoplasty	1 (100 %)	0	0.142
Augmentation of breast using prosthesis	1 (20 %)	4 (80 %)	0.535
Mastopexy	28 (80.0 %)	7 (20 %)	<0.001

Sixty patients had had BCS before BS. These patients were not included in the study cohort. This group of patients comprised mostly women (n=52, 86.7%) with a mean age of 49.9 years and typically had abdominoplasties (91.7%). Most of these operations were performed in public hospitals. The latency between LBCS and BS in this group was a mean of 6.3 (SD 4.2) years.

Length of hospital stay and outpatient clinic visits after LBCS.

Most patients (n=931, 85.5%) had only one hospital stay after LBCS. A synopsis of the details regarding hospital stays and re-admittances and outpatient clinic visits are presented in Table 13. The overall mean length of hospital stay (MLOS) was 3.1 (range 1-68) days after all LBCS procedures combined. After abdominoplasty, the MLOS was 3.1 (range 1-68) days and after body lift 3.6 (range 1-11) days.

Altogether 39 patients (3.6%) were re-admitted during the first week after discharge, and the MLOS was 4.2 days. After abdominoplasty, 32 patients (3.3%) were re-admitted during the first week after discharge, and after a body lift, seven patients (5.4%). Re-admittance during 8 to 30 days after discharge occurred in 119 patients (10.9%) after LBCS. After abdominoplasty, re-admittance during 8 to 30 days after discharge occurred in 102 patients (10.5%), and after a body lift, 17 patients (13.2%). A total of 676 (62.1%) of all 1089 patients after LBCS had outpatient visits within 30 days of operation (Table 13).

Table 13 *Mean length of hospital stay (MLOS) and outpatient visits stratified by the type of LBCS*

	All	Abdominoplasty	Body lift
Mean length of hospital stay (range)	3.1 days (1–68 days)	3.1 days (1–68 days)	3.6 days (1–11 days)
Re-admittance the first week after discharge; MLOS	39 (3.6 %); 4.2 days	32 (3.3 %); 3.8 days	7 (5.4 %); 6.1 days
8–30 days after discharge; MLOS	119 (10.9 %); 4.9 days	102 (10.5%); 4.8 days	17 (13.2 %); 5.4 days
Outpatient visits within 30 days	676 (62.1 %)	595 (61.3 %)	93 (72.1 %)

Complications

Re-operations were recorded for 31 (2.8%) of the 1089 LBCS. The re-operation rate after abdominoplasty was 2.8% and after body lift 3.1%. The most common indication for re-operation was post-operative bleeding (n=24, 2.2%), followed by wound dehiscence (n=5, 0.5%). Only one in-hospital death (0.1%) was recorded, occurring within one month of an abdominoplasty (Table 14).

Table 14 *Summary of re-operations, deaths by type of LBCS*

	All LBCS (%) n= 1089	Abdominoplasty (%) n= 970	Body lift (%) n=129
Any re-operation	31 (2.8 %)	27 (2.8 %)	4 (3.1 %)
Repair of wound dehiscence in surgery of skin	5 (0.5 %)	5 (0.5 %)	0
Reoperation for superficial infection in surgery of skin	1 (0.1 %)	1 (0.1 %)	0
Reoperation for superficial haemorrhage in surgery of skin	24 (2.2 %)	20 (2.1 %)	4 (3.1 %)
Reoperation in surgery of skin	1 (0.1 %)	1 (0.1 %)	0
Death, within one month after operation	1 (0.1 %)	1 (0.1 %)	0

Education levels (Unpublished data)

Of the 7703 patients who had undergone bariatric surgery, 3840 (49.9%) had lower secondary education (Table 15). Altogether 1366 patients (17.7%) had no degree after primary education, or education status was unknown. There was no significant difference in education level between patients who had LBCS after BS and those who had not, except those with lower tertiary education (8.8% vs 9.9%, p= .046).

Table 15 *Education levels of all bariatric surgery patients.*

Education levels		All n=7703 (%)	Bariatric surgery without LBCS n= 6614 (%)	LBCS after bariatric surgery n=1089 (%)	p-value	LBCS of all %
Lower education level ≤ 9 years of education, or education status is unknown	Lower secondary education	3840 (49.9 %)	3269 (49.6 %)	571 (52.4 %)		14.9 %
Intermediate education level = 10-14/15 years of education	Post-secondary non-tertiary education	110 (1.4 %)	99 (1.5 %)	11 (1.0 %)		10.0 %
	First stage of tertiary education	1138 (14.8 %)	993 (15.2 %)	145 (13.3 %)		12.7 %
	Lower tertiary level	748 (9.7 %)	652 (9.9 %)	96 (8.8 %)	0.046	12.8 %
	Upper tertiary level	439 (5.7 %)	391 (5.9 %)	48 (4.4 %)		10.9 %
High education level = 14/15 or more years of education	Doctoral or equivalent	38 (0.5 %)	34 (0.5 %)	4 (0.4 %)		10.5 %

6.2. STUDY II

Altogether 92 women had 122 deliveries after LBCS in Finland between 1999 and 2016 (Table 16). This study cohort was compared with all deliveries (n= 1 028 503). The women who got pregnant after LBCS were older than the comparison group (34 vs 30.1 years, $p < .001$). They had higher BMI in early pregnancy ($p < .001$), shorter length of pregnancy ($p = .009$), Caesarean sections more often ($p < 0.001$), and more outpatient clinic visits in the hospital during pregnancy ($p < .001$).

Table 16 *Characteristics of all pregnancies and deliveries after LBCS compared with all pregnancies and deliveries in Finland during 1999-2016. P-values denote significant correlations between the groups with LBCS and all deliveries*

	All pregnancy and deliveries after LBCS (%)	All pregnancy and deliveries in Finland (%)	p-value
n	122	1028503	
Mean age (SD)	34 (5.1)	30.1 (5.4)	<0.001
BMI*			
<18.5	4 (3.3 %)	50995 (6.8 %)	
18.5–24.9	24 (19.7 %)	181993 (24.3 %)	
25 –29.9	41 (33.6 %)	71062 (9.5 %)	<0.001
30–34.9	21 (17.2 %)	25581 (3.4 %)	
35–	21 (17.2 %)	1238 (0.2 %)	
Unknown	3	110232	
Mean length of pregnancy (SD)	274.5 (15.2)	278.1 (13.5)	0.009
Singleton	118 (96.7 %)	1013259 (98.5 %)	0.101
Low birth weight, (<2500 g)	9 (7.4 %)	45865 (4.5 %)	0.118
Preterm delivery (<37 weeks)	10 (8.2 %)	53650 (5.2 %)	0.139
Post-term delivery (>42 weeks)	2 (1.6 %)	47272 (4.6 %)	0.119
Vaginal delivery	86 (70.5 %)	858855 (83.5 %)	<0.001
Caesarean section	36 (29.5 %)	168669 (16.4 %)	
Planned	20 (16.4 %)	70386 (6.8 %)	<0.001
Urgent	14 (11.5 %)	64189 (6.2 %)	0.017
Emergency	2 (1.6 %)	8496 (0.8 %)	0.321
Other	0	25598 (2.5 %)	0.078
Parity			
0	28 (23.0 %)	365428 (35.5 %)	
1	23 (18.9 %)	125244 (12.2 %)	
2	30 (24.6 %)	48657 (4.7 %)	<0.001
3	23 (18.9 %)	15241 (1.5 %)	
4	14 (11.5 %)	4784 (0.5 %)	
≥5	4 (3.3 %)	4370 (0.4 %)	
Termination of pregnancy			
0	100 (82.0 %)	493508 (48.0 %)	0.084
≥1	22 (18.0 %)	70939 (6.9 %)	
Miscarriage			
0	89 (73.0 %)	466383 (45.3 %)	0.115
≥1	33 (27.0 %)	98064 (9.5 %)	
Visits in maternity clinics** (SD)	16.1 (5.3)	16.5 (5.3)	0.821
Visits in hospital outpatient clinic (SD)	5.3 (3.2)	3.1 (2.7)	<0.001

*Self-reported BMI in early pregnancy. Information collected from the Medical Birth Register since 2004.
** The Ministry of Social Affairs and Health is responsible for guiding the development of maternity and child health clinics. Municipalities are in charge of the practical arrangement of services.

First pregnancies and deliveries after LBCS

The focus of this data was on first pregnancies and deliveries after LBCS. The specific inclusion criteria resulted in 92 women who had LBCS before pregnancy and delivery. This group was compared with all first deliveries (n = 564 447). None of the mothers or children died in pregnancy or delivery. The women with preceding LBCS were older (33.5 vs 29.6 years, p< .001) (Table 17).

Pregnancy

The women with LBCS had a shorter mean length of pregnancy (274.2 vs 278.1 days, p= .019) and more outpatient clinic visits in the hospital during pregnancy (5.5 vs 3.1 visits, p< .001) than women without LBCS. There was no significant difference in numbers of previous induced terminations of pregnancies (p = .163) or visits to maternity clinics during the pregnancy (p = .466).

Delivery

Caesarean sections were more common in women who had LBCS (34.8% vs. 18.9%, p < .001), with considerably more planned Caesarean sections (20.7% vs, 6.9%, p < .001) in this group. However, no statistical differences emerged in urgent (decision-to-delivery < 30 min) Caesarean sections (p = .103) or emergency (immediate delivery) Caesarean sections (p= .216). Women with preceding LBCS, 8.7% had more preterm births (<37 weeks) compared with those with no preceding LBCS 2.5%, *(*p< .001), and also more previous miscarriages after LBCS (26.1% vs. 17.4%, p = .027). There was no significant difference in the proportion of low-birth-weight babies (7.6% vs. 4.4%, p= .138).

Table 17 *First pregnancies and deliveries with or without preceding LBCS in Finland during 1999-2016. The p-value denotes significant correlations between the groups with LBCS and all deliveries*

	First pregnancy and deliveries in Finland (%)	First pregnancy and delivery after LBCS (%)	p-value
n	564447	92	
Mean age (SD)	29.6 (5.6)	33.5 (5.1)	<0.001
BMI*			
< 18.5	50995 (11.6 %)	2 (2.3 %)	
18.5–24.9	181993 (41.3 %)	21 (24.4 %)	<0.001
25–29.9	71062 (16.1 %)	31 (36.0 %)	
30–34.9	25581 (5.8 %)	16 (18.6 %)	
35–	1238 (0.3 %)	13 (15.1 %)	
Unknown	110232 (25 %)	3 (3.5 %)	
Mean length of pregnancy , days (SD)	278.1 (13 %)	274.2 (16 %)	0.019
Singleton	555015 (98.3 %)	90 (97.8 %)	0.707
Low birth weight, (<2500 g)	24982 (4.4 %)	7 (7.6 %)	0.138
Preterm delivery (<37 weeks)	13881 (2.5 %)	8 (8.7 %)	<0.001
Post-term delivery (>42 weeks)	29888 (5.3 %)	0	0.023
Vaginal delivery	457391 (81.0 %)	60 (65.2 %)	
Caesarean section	106438 (18.9 %)	32 (34.8 %)	<0.001
Planned	38821 (6.9 %)	19 (20.7 %)	<0.001
Urgent	42247 (7.5 %)	11 (12.0 %)	0.103
Emergency	5271 (0.9 %)	2 (2.2 %)	0.216
Other	20099 (3.6 %)	0	0.065
Parity			
0	365428 (64.7 %)	28 (30.4 %)	
1	125244 (22.2 %)	14 (15.2 %)	<0.001
2	48657 (8.6 %)	26 (28.3 %)	
3	15241 (2.7 %)	15 (16.3 %)	
4	4784 (0.8 %)	8 (8.7 %)	
≥5	43700 (0.8 %)	1 (1.1 %)	
Termination of pregnancy			
0	493508 (87.4 %)	76 (82.6 %)	0.163
≥1	70939 (12.6 %)	16 (17.4 %)	
Miscarriage			
0	466383 (82.6 %)	68 (73.9 %)	0.027
≥1	98064 (17.4 %)	24 (26.1 %)	
Visits in maternity clinics** (SD)	16.2 (5.4)	16.6 (5.4)	0.466
Visits in hospital outpatient clinic (SD)	3.1 (2.7)	5.5 (4.4)	<0.001

*Self-reported BMI in early pregnancy. Information collected from the Medical Birth Register since 2004.
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Bariatric group

The bariatric group comprised 26 women (28.3%) with altogether 33 deliveries. All first pregnancies were singleton. The mean age of these women was 35.9 years, and the mean BMI in early pregnancy was 32 kg/m^2 (Table 18).

There were 22 patients (84.6%) who had undergone RYGB, one (3.8%) had SG and 3 (11.5%) had other bariatric procedures (not specified). There were 23 (88.5%) abdominoplasty and 3 (11.5%) body lift procedures in this group. The majority (92.3%) of LBCS procedures were done in public hospitals, the rest in private hospitals.

The mean latency between LBCS and delivery was 2.67 (range 1.04–6.52) years. Two women (7.7%) had one or more terminations of pregnancy, and eight women (30.8%) had one or more previous miscarriages.

The mean length of pregnancy was 271.2 (SD 18.3) days. Low birth weight (< 2500 g) was recorded in 15.4% of deliveries. Two women (7.7%) had preterm delivery (<37 weeks). Eighteen women (69.2%) had vaginal deliveries and 8 (30.8%) Caesarean sections. In total, 5 (19.2%) planned sections and 3 (11.5%) urgent sections were recorded. There were no emergency sections in this group. Altogether 53.8% had no prior births, 15.4% had one previous birth, 19.2% had two births, 7.7% had three births, and 3.8% had four births. No women had five or more prior births in this group.

Non-bariatric group

The non-bariatric group comprised 66 women (71.7%) with a total of 89 deliveries. Of the first deliveries after LBCS, 64 (97.0%) were singleton births. The mean age of these mothers was 33.2 years, and the mean early pregnancy BMI was 27.2 kg/m^2 (Table 18).

In this group, 56 abdominoplasty procedures (84.8%), six body lifts (9.1%), and four other aesthetic corrections on the skin of the trunk (6.1%) were recorded. Of the procedures, 59.1% were done in public hospitals and the remainder in private hospitals.

The mean latency between LBCS and delivery was 4.41 (range 0.63–13.02) years. There were 14 women (21.2%) with at least one previous termination of pregnancy and 16 (24.2%) with at least one previous miscarriage.

The mean length of pregnancy was 275.4 (SD 14.9) days. Low birth weight (< 2500 g) was recorded in three deliveries (4.5%). Six women (9.1%) had preterm delivery (<37 weeks). Forty-two births (63.6%) were vaginal deliveries and 24 (36.4%) Caesarean sections. In total, 14 (21.2%) planned, eight (12.1%) urgent, and two (3.0%) emergency sections were recorded. Of the women, 21.2% had no prior births, 15.2% had one previous birth, 31.8% had two births, 19.7% had three births, 10.6% had four births, and 1.5% had five or more births.

Comparison of bariatric and non-bariatric groups

Statistical analysis revealed significant differences between the bariatric and non-bariatric groups in mean age ($p = .025$), mean BMI in early pregnancy ($p < .001$), and parity ($p = .006$). LBCS was performed in a public hospital more often in the bariatric group ($p = .005$).

The bariatric and non-bariatric cohorts had undergone similar types of LBCS (abdominoplasty $p= .339$ and body lift $p = .722$) and had similar rates of previous terminations of pregnancy ($p = .148$) and miscarriages ($p= .872$). There were no significant differences in length of pregnancy ($p= .301$) and number of low-birth-weight babies ($p= .065$) or preterm deliveries ($p = .893$) (Table 18).

Table 18 *Demographic characteristics of the first pregnancies and deliveries after LBCS in Finland in 1999-2016. The p-values denote significant correlations between the groups with and without preceding bariatric operation before LBCS.*

	Bariatric group	Non-bariatric group	p-value
n	26	66	
Mean age (SD)	35.9 (5.3)	33.2 (4.9)	0.025
Mean BMI* (SD)	32.0 (4.7)	27.2 (4.9)	<0.001
Sleeve gastrectomy	1 (3.8 %)	N/A	0.109
Gastric bypass	22 (84.6 %)	N/A	<0.001
Other	3 (11.5 %)	N/A	0.005
Abdominoplasty	23 (88.5 %)	56 (84.8 %)	0.339
Body lift	3 (11.5 %)	6 (9.1 %)	0.722
Other aesthetic corrections on the skin of the trunk	0	4 (6.1 %)	0.199
Hospital, where LBCS were done			
In public hospital	24 (92.3 %)	39 (59.1 %)	0.005
In private hospital	2 (7.7 %)	27 (40.9 %)	
Mean length of pregnancy, days (SD)	271.2 (18.3)	275.4 (14.9)	0.301
Singleton	26 (100 %)	64 (97.0 %)	0.443
Low birth weight, (<2500 g)	4 (15.4 %)	3 (4.5 %)	0.065
Pre-term delivery (<37 weeks)	2 (7.7 %)	6 (9.1 %)	0.893
Pre-term delivery (>42 weeks)	0	0	NA
Vaginal delivery	18 (69.2 %)	42 (63.6 %)	0.470
Caesarean section	8 (30.8 %)	24 (36.4 %)	
Planned	5 (19.2 %)	14 (21.2 %)	0.938
Urgent	3 (11.5 %)	8 (12.1 %)	0.986
Emergency	0	2 (3.0 %)	0.385
Parity			
0	14 (53.8 %)	14 (21.2 %)	
1	4 (15.4 %)	10 (15.2 %)	
2	5 (19.2 %)	21 (31.8 %)	0.006
3	2 (7.7 %)	13 (19.7 %)	
4	1 (3.8 %)	7 (10.6 %)	
≥5	0	1 (1.5 %)	
Termination of pregnancy			
0	24 (92.3 %)	52 (78.8 %)	0.148
≥1	2 (7.7 %)	14 (21.2 %)	
Miscarriage			
0	18 (68.2 %)	50 (75.8 %)	0.872
≥1	8 (30.8 %)	16 (24.2 %)	
Visits in maternity clinics** (SD)	16.3 (6.0)	16.7 (5.3)	0.744
Visits in hospital outpatient clinic (SD)	6.4 (4.0)	5.1 (4.5)	0.167

*Self-reported BMI in early pregnancy. Information collected from the Medical Birth Register since 2004.
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Pre-delivery diagnoses

Gestational diabetes mellitus (GDM) was more common in the non-bariatric group than in the bariatric group (54.5% vs. 2.2%, $p < .001$) (Table 19). Excessive foetal growth associated with GDM was only recorded in the non-bariatric group (9 [27.3%] $p < .001$). Fear of childbirth was more prevalent in the non-bariatric group than in the bariatric group (5 [15.2%]) vs. 3 [3.4%], $p = .02$). Uterine scarring from previous surgery was more prevalent in the non-bariatric surgery group (25 [75.8%] vs. 5 [5.6%], $p < .001$).

There is no definitive diagnosis code for rectus diastasis, and empirically, we know that in Finland, the code “Ventral hernia without obstruction or gangrene (K43.9)” is used to denote rectus diastasis. The diagnosis “Ventral hernia without obstruction or gangrene” was more common in the non-bariatric group than in the bariatric group, and in both circumstances (first delivery after LBCS and all deliveries after LBCS), the difference reached statistical significance ($p= .023$ and $p= .019$, respectively).

Table 19 *Most common obstetric pre-delivery diagnoses (and ICD-10 codes) for the bariatric and non-bariatric groups in first delivery after LBCS and all deliveries after LBCS. The p-values denote significant correlations between the groups with and without preceding bariatric operation before LBCS.*

	The first delivery after LBCS			All deliveries after LBCS		
Pre -delivery diagnosis (ICD-10 codes)	Bariatric group	Non-bariatric group	p-value	Bariatric group	Non-bariatric group	p-value
Pre-existing essential hypertension (O10.0)	0	1 (1.5 %)	0.528	0	1 (1.1 %)	0.541
Hypertension gravidarum (O13)	3 (4.5 %)	3 (11.5 %)	0.221	5 (5.6 %)	4 (12.1 %)	0.222
Pre-eclampsia, unspecified (O14.9)	0	1 (3.0 %)	0.099	0	1 (3.8 %)	0.109
Gestational diabetes mellitus (O24.4)	2 (3.0 %)	16 (61.5 %)	<0.001	2 (2.2 %)	18 (54.5 %)	<0.001
Maternal care for excessive fetal growth (O36.6)	0	8 (30.8 %)	<0.001	0	9 (27.3 %)	<0.001
Polyhydamnion (O40.0)	0	4 (15.4 %)	0.001	0	4 (12.1 %)	0.001
Fetal distress during labor (O68.0)	3 (4.5 %)	3 (11.5 %)	0.221	4 (4.5 %)	3 (9.1 %)	0.332
Mental disorders and diseases of the nervous system complicating pregnancy, childbirth and the puerperium (O99.3)	1 (1.5%)	1 (3.8%)	0.490	1 (1.1 %)	1 (3.0 %)	0.461
Fear of childbirth (O99.8)	3 (4.5%)	4 (15.4%)	0.077	3 (3.4 %)	5 (15.2 %)	0.020
Ventral hernia without obstruction or gangrene (K43.9)	0	2 (7.7%)	0.023	0	2 (6.1 %)	0.019
Maternal care due to uterine scar from previous surgery (O34.2)	5 (7.6 %)	22 (84.6 %)	<0.001	5 (5.6 %)	25 (75.8 %)	<0.001

Risk factor analyses

The results of univariate analysis of the potential risk for low birth weight, preterm delivery, or Caesarean section, evaluated with such risk factors as the latency between LBCS and delivery, maternal age, parity, mean BMI in early pregnancy, and preceding bariatric operations, are presented in Table 20.

The background-adjusted risk for the Caesarean section in the non-bariatric group was OR 2.64, 95% CI 1.58–4.40. The adjusted risk for pre-term delivery (<37 weeks) in the non-bariatric group was OR 2.20; 95% CI 1.01–4.79. The adjusted risk for low birth weight (<2500 g) in the bariatric group was OR 4.30; 95% CI 1.50–12.31. All other variables failed to predict an increased risk for low birth weight, pre-term delivery, or Caesarean section.

Table 20 *Risk factors for Caesarean section, pre-term delivery (<37 weeks), and low birth weight (<2500 g) compared with all deliveries (n=1 028 503) in Finland during 1999-2016*

Odds Ratio Estimates and Wald Confidence Intervals								
Caesarean section			Pre-term delivery (<37 weeks)			Low birth weight (< 2500 g)		
Study Variable	OR	95 % Cl	Study Variables	OR	95 % Cl	Study variables	OR	95 % Cl
Year between LBCS and delivery	0.992	(0.990–0.993)	Year between LBCS and delivery	1.003	(0.999–1.006)	Year between LBCS and delivery	1.001	(0.997–1.005)
Maternal age	1.071	(1.070–1.073)	Maternal age	1.017	(1.015–1.019)	Maternal age	1.021	(1.019–1.024)
Parity	0.682	(0.677–0.687)	Parity	0.919	(0.909–0.929)	Parity	0.847	(0.835–0.858)
BMI*	1.056	(1.055–1.058)	BMI *	1.012	(1.010–1.014)	BMI*	0.993	(0.990–0.996)
Bariatric group	0.939	(0.425–2.076)	Bariatric group	1.190	(0.284–4.990)	Bariatric group	4.298	(1.500–12.312)
Non-bariatric group	2.637	(1.580–4.401)	Non-bariatric group	2.197	(1.009–4.785)	Non-bariatric group	1.990	(0.726–5.456)

6.3. STUDY III

The inclusion criteria resulted in a sample of 158 patients who had preceding MWL following LBCS between 2009 and 2015. Their mean age was 44.8 years, ranging from 22 to 72 years. There were 117 women (74.1%) with a mean age of 44.1 years and 41 men (25.9%) with a mean age of 46.7 years. The mean highest lifetime weight was 136.5 (range 79–285) kg, and the mean highest lifetime BMI was 47.6 (range 31.9–90.97) kg/m². The mean weight loss was 54.4 kg. The majority (n=112, 70.9%) underwent abdominoplasty and 46 (29.1%) had body lift. Altogether 39 patients (24.7%) had T2DM, 63 (39.9%) had arterial hypertension, and 37 (23.4%) had hyperlipidemia. Twenty-seven patients (17.7%) were active smokers, and 22 (13.9%) were ex-smokers. Sixty-nine patients (43.7%) had some abdominal surgery previously (Table 21).

Table 21 *Demographic characteristics of all 158 patients who underwent LBCS after MWL during 2009 and 2015 in Finland.*

Total	158
Female	117 (74.1 %)
Male	41 (25.9 %)
Mean age	
All (range)	44.8 years (22–72)
Female	44.1 years
Male	46.7 years
The mean highest lifetime body weight (range)	136.5 kg (79 –285)
The mean highest lifetime BMI (range)	47.6 kg/m² (31.90– 90.97)
Co-morbidities	
T2DM	39 (24.7 %)
Arterial hypertension	63 (39.9 %)
Hyperlipidaemia	37 (23.4 %)
Active smoker	28 (17.7 %))
Ex-smoker	22 (13.9 %)
Abdomen surgery before	69 (43.7 %)

Bariatric and non- bariatric groups

There were 90 patients (56.9%) with a mean age of 46 years in the bariatric group and 68 patients (43.0%) with a mean age of 43 years in the non-bariatric group. The mean time between BS and LBCS was 2.69 years. Table 22 demonstrates the demographic characteristics of both the bariatric and non-bariatric groups.

Comparison of bariatric and non-bariatric groups

Lifetime maximum BMI was significant higher in the bariatric than non-bariatric group (49.0 vs. 45.8 kg/m[2], p= .0069). Patients in the bariatric group had lost more weight (56.8 vs. 51.2 kg, p= .0124). Further, the non-bariatric group recorded less diabetes (p= .0311), less arterial hypertension (p= .0028), and less active smokers (p= .0305).

No significant differences emerged between the two groups in mean age (p= .091), maximum weight before weight loss (p=.116), arterial hypertension (p= .0167), hyperlipidemia (p= .0167), or whether there had been any surgery of the abdominal area before contouring surgery (p= .9216) (Table 22).

Table 22 *Demographic characteristics of 158 patients who underwent LBCS after MWL. The p-values denote the correlation between bariatric and non-bariatric patients.*

	Bariatric group	Non-bariatric group	p-value
Total	90 (56.9 %)	68 (43.0 %)	0.388
Female	69 (76.7 %)	48 (70.6 %)	
Male	21 (23.3 %)	20 (29.4 %)	
Mean age (range)			
All	46.0 years (24–64)	43.0 years (22–72)	0.091
Female	45.1 years (24–62)	42.5 years (22–72)	
Male	48.9 years (24–64)	44.3 years (22–72)	
The mean highest lifetime body weight (range)	39.5 kg (96–285)	132.4 kg (79–267)	0.116
The mean highest lifetime BMI (range)	49.0 kg (37–0.97)	45.8 kg (31.90–82.41)	0.007
Mean weight (range)	83.2 kg (55–150)	83.5 kg (60–132)	0.829
Mean Weight loss (range)	56.8kg (27.5–135).	51.2 kg (9.4–157)	0.012
Co-morbidities			
T2DM	28 (31.1%)	11 (16.2 %)	0.0311
Arterial hypertension	45 (50 %)	18 (25.6 %)	0.0028
Hyperlipidaemia	26 (28.9 %)	11 (16.2 %)	0.062
Active smoker	21 (23.3 %)	7 (10.3 %)	0.0305
Ex-smoker	15 (16.7 %)	7 (10.3 %)	
Abdomen surgery before	39 (43.3 %)	30 (44.1 %)	0.9216

All complications

Ninety-six complications were recorded in 80 patients. The overall complication rate was 51%. Most patients (n=64, 80%) had only one complication. Sixteen patients (20%) had two recorded complications. Figure 14. presents all recorded complications in the study period.

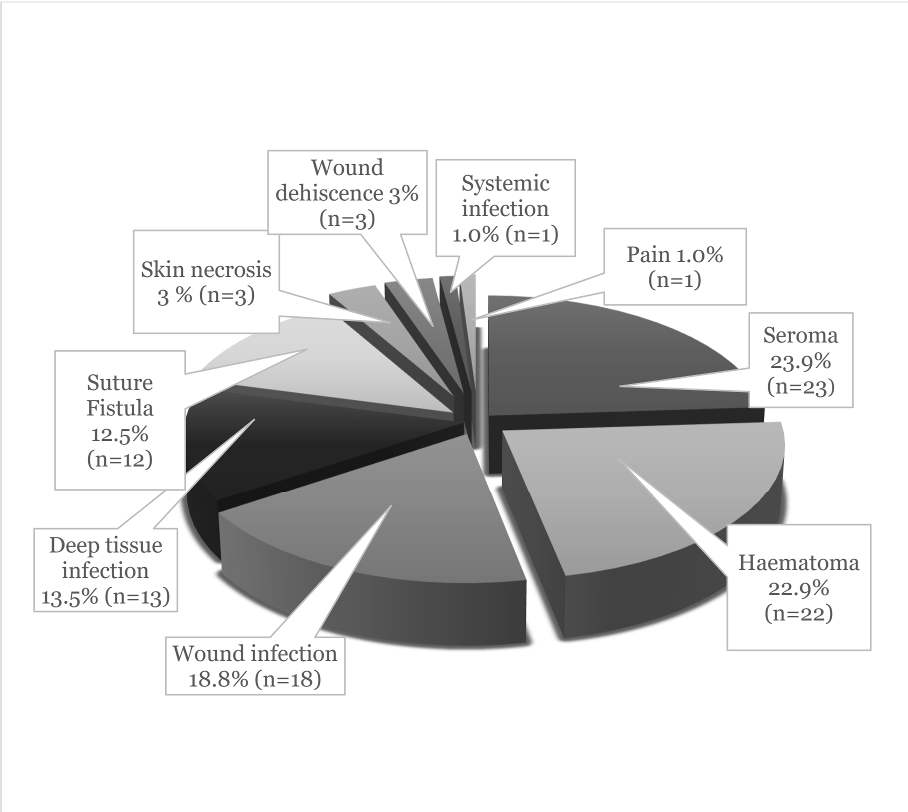


Figure 14 *All post-operative complications after LBCS in 158 patients during 2009– 2015 in Finland*

Seromas

The most frequent complication was seroma (n=23, 23.9%). Most of the seromas occurred at least eight days after the operation. However, two cases of seroma were recorded before eight post-operative days, and three cases were recorded more than 30 days after the operation. One patient (0.6%) had no drains at all after the operation. Eighty-two patients (51.9%) returned home from the hospital with at least one drain. Seventy-five patients (47.5%) had all drains removed before discharge from the hospital.

Haematomas

Haematoma-related complications were the second most common complication, occurring in 22 cases (22.9%). In five (22.7%) of all haematomas cases, the post-operative haematoma was noted and left to resolve without any intervention. In nine cases (40.9%), post-operative bleeding required surgical intervention with blood transfusion, and in eight cases (36.3%), blood transfusion was the only intervention (Figure 15).

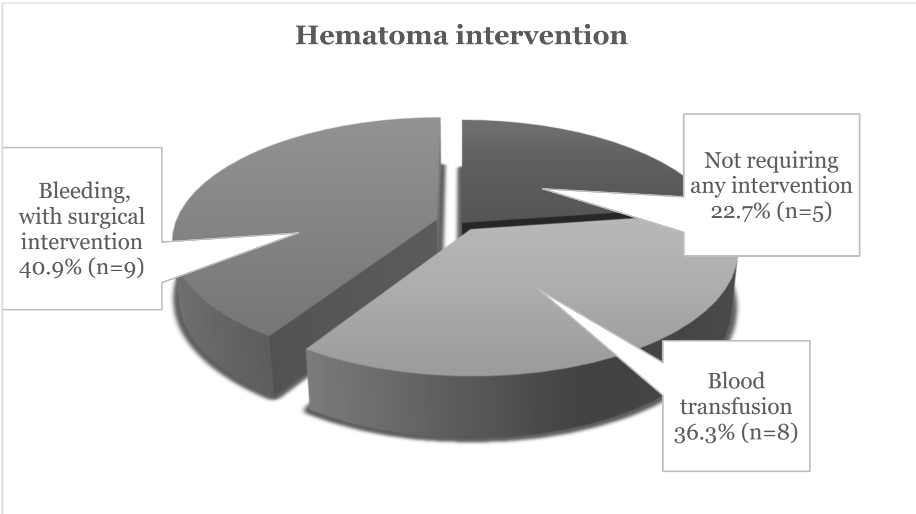


Figure 15 *Interventions for haematoma (n=22) complications.*

Wound-related complications

There were 36 wound-related complications, including wound infections (n=18, 50%), wound dehiscence (n=3, 8%), skin necrosis (n=3, 8%), and suture fistula (n=12, 34%). In six cases, surgical intervention was necessary (Figure 16).

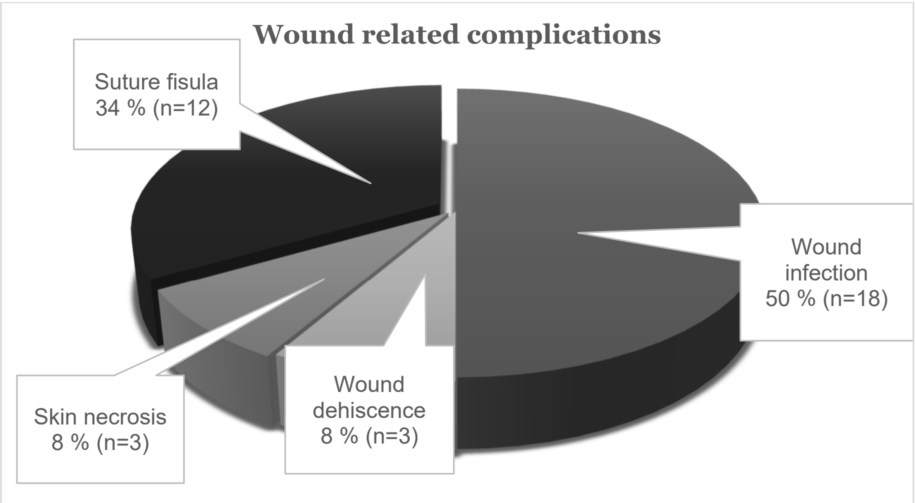


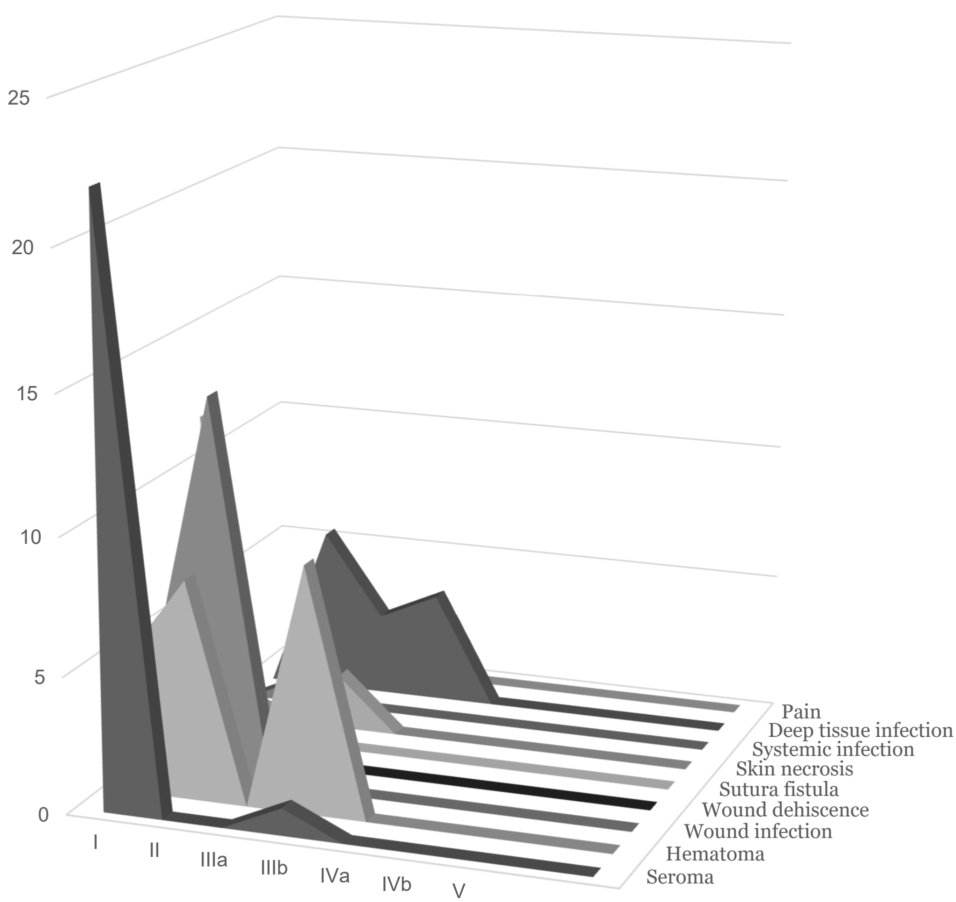
Figure 16 *Wound-related complications (n=36)*

Infections

Any Infections occurred in 32 cases (33%). Wound infections were recorded in 18 cases (18.8%), deep tissue infection in 13 cases (13.5%), and systemic infection in one case (1.0%). Altogether 14 wound infections were recorded as a late complication, one case before eight post-operative days, and three cases more than 30 days after the procedure.

Clavien-Dindo classification

Complication grades according to the Clavien–Dindo classification were grade I: 46 (47.9%), grade II: 31 (32.3%), grade IIIa: 5 (5.2%), and grade IIIb: 14 (14.6%). No grade IV or grade V complications were recorded. Most complications (n=77, 80.2%) were minor (Clavien-Dindo grades I and II). Major complications (Clavien-Dindo grades IIIa and IIIb) afflicted 19 patients (19.8%). Altogether 14.6% of patients needed a surgical intervention (Figure 17).



	I	II	IIIa	IIIb	IVa	IVb	V		
Seroma	22	0	0	1	0	0	0		
Hematoma	5	8	0	9	0	0	0		
Wound infection	4	14	0	0	0	0	0		
Wound dehiscence	1	2	0	0	0	0	0		
Sutura fistula	12	0	0	0	0	0	0		
Skin necrosis	1	0	2	0	0	0	0		
Systemic infection	0	1	0	0	0	0	0		
Deep tissue infection	0	6	3	4	0	0	0		
Pain	1	0	0	0	0	0	0		

Figure 17 *Complications stratified by the Clavien-Dindo classification.*

Immediate complications (0-24 h post-operatively) were recorded in eight cases (8.3%). Early complications (1-7 days post-operatively) affected 16 cases (16.7%) and late complications (8-30 days post-operatively) 56 cases (58.3%). Complications more than 30 days after the procedure were recorded in 16 cases (16.7%), the most common reason being suture fistula (n=7) (Figure 18).

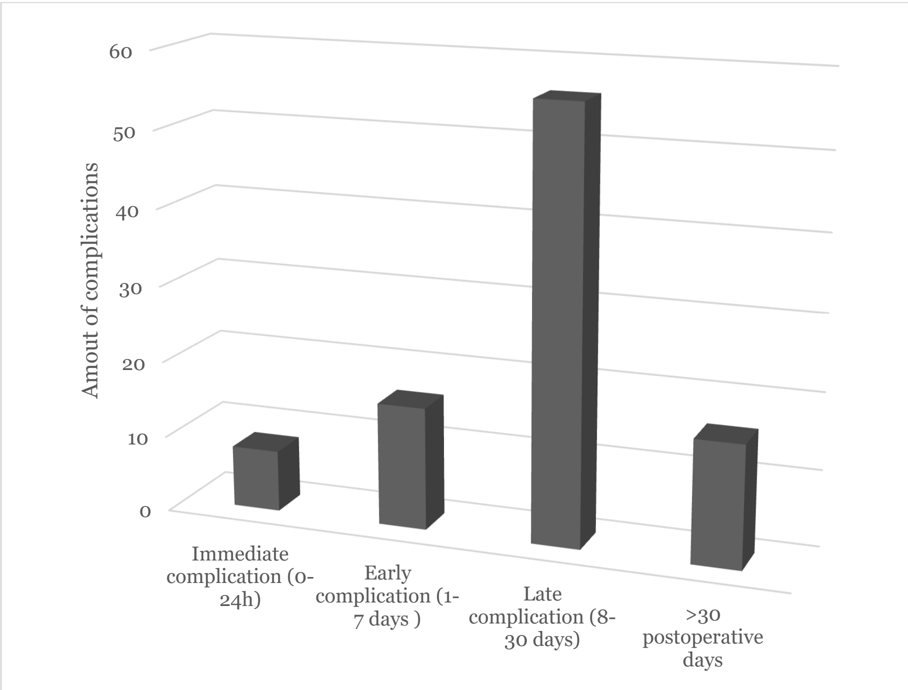


Figure 18 *Complications classification by the time of the event.*

Risk factors for complications

Statistically, significant risk factors were older age (p= .042) at operation for immediate haematoma needing surgical intervention. High maximum weight (p=0.035) and high pre-operative weight (p=0.0053) correlated significantly with haematoma requiring surgical intervention for early complications. For late complications, the occurrence of seroma was associated with older age (p= .0061).

Comparison of abdominoplasty and body lift

There was a slight significance between post-operative bleeding and surgical intervention in the body lift group (p=0.0043). However, there were no differences in wound-related complications. (Table 23).

Table 23 *Complications stratified by the method of weight loss and LBCS*

	Bariatric group, complications n=31 (%)	Non -bariatric group, complications n=34 (%)	
Wound infection	3 (10 %)	9 (26 %)	Abdominoplasty
Wound dehiscence	1 (3 %)	2 (6 %)	
Skin necrosis	2 (6 %)	1 (3 %)	
Fistula	6 (19 %)	1 (3 %)	
Postoperative Hematoma	5 (16 %)	5 (15 %)	
Seroma	8 (26 %)	9 (26 %)	
Deep tissue Infection	5 (16 %)	7 (21 %)	
Systemic infection	1 (3 %)	0	
	Bariatric group, complications n=19 (%)	Non -bariatric group, complications n=10 (%)	
Wound infection	5 (26 %)	1 (10 %)	Body lift
Wound dehiscence	0	0	
Skin necrosis	0	0	
Fistula	1 (5 %)	3 (30 %)	
Postoperative Hematoma	6 (32 %)	6 (60 %)	
Seroma	6 (32 %)	0	
Deep tissue Infection	1 (5 %)	0	
Systemic infection	0	0	

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6.4. STUDY IV

A total of 23 patients gave written informed consent to participate in the study. Their mean age was 45.7 (range 28-67) years. There were 18 women (78.3%) and five men (21.8 %). Table 24 demonstrates the characteristics of the patients.

Table 24 *Subjects characteristics*

	All	Range
n	23 (100 %)	
Mean age (SD)	45.7 (9.9)	28–67
Women Mean age (SD)	18 (78.3 %) 48.2 (8.2)	37–67
Men Mean age (SD)	5 (21.8 %) 36.4 (10.8)	28–54
Bariatric surgery	17 (73.9 %)	
Lifestyle change	6 (26.1 %)	
Mean weight before weight loss (SD)	137.1 kg (21.5)	94–170
Mean BMI* before weight loss (SD)	39 kg/m² (4.2)	36–60.2
Mean weight in plastic surgery outpatient clinic visit (SD)	77.0 kg (11.5)	53.5–97
Mean BMI* in plastic surgery outpatient clinic visit (SD)	26.9 kg/m² (2.2)	22–30.47
Mean weight loss (SD)	60.0 kg (14.7)	31–85
Non-smoking Smoking Former smoker	15 (65.2 %) 1 (4.3 %) 7 (30.4 %)	
Hypertension T2DM Dyslipidaemia	6 (26.1 %) 5 (21.7 %) 3 (13.0 %)	

Hand grip strength test

The results of the hand grip strength test varied from 16 kg to 50 kg. The best result among women was 38 kg and among men 50 kg. The majority, 14 patients (60.9%), reached level 1 (poor) in age- and gender-matched and grip strength. Six patients (26.1%) reached level 2 (fair), one (4.3%) level 3 (average), and 2 (8.7%) level 4 (good) (Table 6). None of the patients attained level 5 (excellent) in this particular test. The mean hand grip strength results were 27.6 (range 16-45) kg for those who had undergone BS and 36 (range 22-50) kg for those who lost weight by lifestyle changes (Table 25).

Dynamic muscle strength of body test

In the dynamic muscle strength of body test, the results varied from 0 to 15. Five participants (21.5%) reached the maximum number of sit-ups (15 sit-ups). Sixteen patients (69.6%) reached level 1 (0-5 sits-ups) and two patients (8.7%) level 2 (6-14 sits-ups). One participant (4.3%) was unable to complete a single sit-up.

Squat test

The best result of the squat test was 30 squats in 30 seconds, with a mean of 17.7 (range 10–30) squats. The poorest result was ten squats. Two participants (8.7%) attained level 1, four (17.4 %) level 2, seven (30.4%), level 3, seven (30.4%) level 4, and three (13%) level 5. The mean results in 30 seconds among post-bariatric patients was 17.3 squats, and among those who had changed their lifestyle habits, 18.7 squats (Table 25, Figure 19).

Table 25 *Results and fitness levels in all three fitness tests*

Fit test/ fitness class	1 (Poor)	2 (Fair)	3 (Average)	4 (Good)	5 (Excellent)
Hand grip strength	14 (60.9 %)	6 (26.1 %)	1 (4.3 %)	2 (8.7 %)	0 (0)
Dynamic muscle strength of body	16 (69.6 %)		2 (8.7 %)		5 (21.7 %)
Squatting test	2 (8.7 %)	4 (17.4 %)	7 (30.4 %)	7 (30.4 %)	3 (13.0 %)
	Under average		average	Above average	

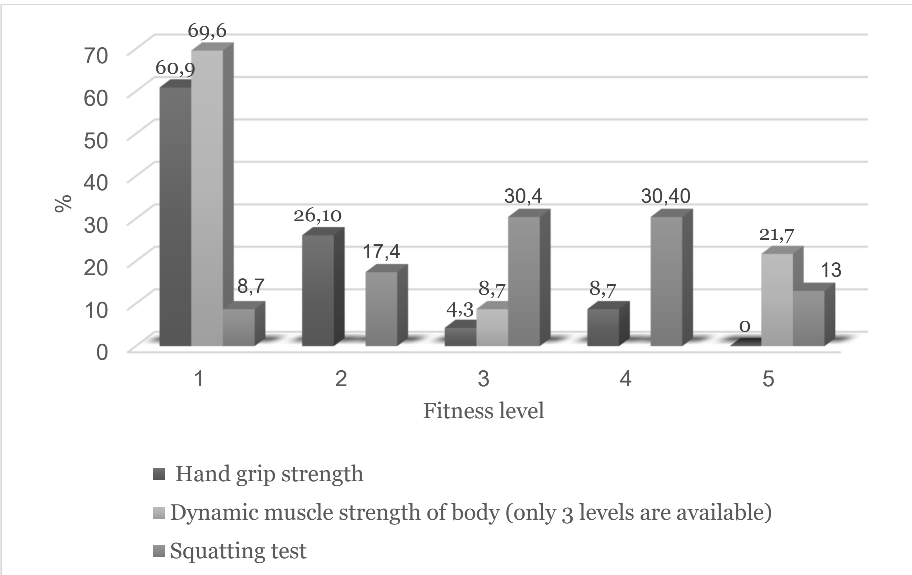

Figure 19 *Fitness class-related distribution of subjects in the fitness tests*

7 DISCUSSION

7.1. OBESITY AND MASSIVE WEIGHT LOSS

Worldwide, obesity is on the rise (Finkelstein et al., 2021). BS is currently considered the most effective long-term management for severe obesity and reduces the impact of obesity-related co-morbidities (Angrisani et al., 2018a). The prevalence of BS has increased in recent decades and is continuing to rise (Buchwald et al., 2013). The sleeve gastrectomy and gastric bypass procedures are the most performed bariatric procedures to maintain or achieve weight loss (Luca et al., 2016). These operations cover 45-85% of all bariatric procedures (Angrisani et al., 2018; Bockelman et al., 2017). In addition to BS, MWL can also be achieved by a lifestyle intervention based on dietary restriction and habitual physical activity (Wadden et al., 2007). However, these results tend not to be as effective and long-lasting as after BS (Montesi et al., 2016; Webb et al., 2017). In **Study III**, 57% of the participants underwent BS and 43% non-bariatric approaches to weight loss. In **Study IV**, 73.9% of all patients had to precede MWL by BS and 26.1% by non-bariatric methods. In **Study II**, bariatric patients accounted for 28.3% of the study cohort. In addition, it was impossible to reliably verify how many women who underwent LBCS had preceding MWL due to lifestyle changes in the **Study II** setting. However, these figures are somewhat concordant compared with previous literature, with proportions of non-bariatric patients typically ranging between 10% and 40.4% (de Kerviler et al., 2009; Gusenoff et al., 2009; Shermak et al., 2008).

7.2. LOWER BODY CONTOURING SURGERY

Most patients who have experienced MWL suffer from redundant, heavy skin folds and might face many problems due to hanging surplus skin. The resulting deformities cannot be addressed adequately with exercise or diets; the only efficient and durable intervention is the surgical removal of the excess skin (Herman et al., 2015). BCS after MWL aims to treat both the functional and aesthetic problems caused by redundant skin, increasing the patient's quality of life and self-esteem (Klassen et al., 2012; Modarressi et al., 2013). Furthermore, BCS after MWL plays an important role in weight loss, weight stabilization, and prevention of weight regain (de Vries et al., 2019; de Zwaan et al., 2014). A previous study demonstrated that patients who underwent BCS after RYGB were able to lose significantly more total weight than those who did not undergo BCS (35.6% vs 30.0%, $p < .05$) during a five-year follow-up (Smith et al., 2018).

The abdomen and lower body are objectively and subjectively mentioned as the locations with the most severe deformities after MWL (Giordano et al., 2013; Kitzinger et al., 2012a). Typically, an LBCS of either abdominoplasty or body lift is the first step for BCS after MWL. Abdominoplasty is the more common procedure (Lazzati et al., 2018). In **Study I,** most (89%) of the LBCS patients had abdominoplasty, and only 11% had a body lift. In **Study II,** 85.9% of all LBCS were abdominoplasties, 9.8% were body lifts, and the remaining 4.4% were other aesthetic corrections on the skin of the trunk (not specified). In **Study III,** most patients, nearly 71%, underwent abdominoplasty, and 29% underwent body lift.

In the literature, women are claimed to have significantly more problems than men due to redundant skin and undergo BCS more often after MWL (Kitzinger et al., 2012a; Staalesen et al., 2014). The results of this thesis support previous findings. **Study I** contained 16.9% men and 83.1% women, for a gender ratio of 1:4.9. The patients who underwent LBCS after BS were also statistically younger than the comparison bariatric group without LBCS ($p<0.001$). **Study III** contained a sample of 158 patients, comprising 74.1% women and 25.9% men.

BCS is performed approximately two to three years after BS, which corresponds well to the time of weight stabilization (Bossert et al., 2012; Lazzati et al., 2018). This growth reaches a plateau around the fifth year after BS. In **Study I,** the numbers of LBCS began to grow two years after the BS, which has also been reported previously (Lazzati et al., 2018).

There is a consensus that LBCS should not be performed earlier than 12 to 18 months after BS (Soldin et al., 2014). This time window could be even later. Bodyweight must first stabilize after BS before considering any BCS. The weight reduction is fastest during the first year after BS, and during this time, the BMI is most unstable. It also takes at least 12 months before eating habits stabilize and nutrition storages begin to fill up (Balague et al., 2013). Stable and as close to normal weight as possible generally results in the best aesthetic outcome.

7.3. PREVALENCE OF LOWER BODY CONTOURING IN FINLAND

LBCS after MWL is becoming increasingly popular, in line with the growing numbers of BS over the past two decades (Angrisani et al., 2018a). **Study I** reviewed the national registry data on bariatric patients with LBCS in Finland during 1998-2016. This thesis demonstrated an increased rate of both bariatric and post-bariatric procedures. Altogether, 1089 post-bariatric patients (14.1%) of 7703 underwent LBCS. The prevalence of LBCS seems to be on the rise in the last decade. Based on these numbers, the popularity of post-bariatric BCS has risen considerably, and BCS is the fastest-growing field in public plastic surgery. However, the incidence of LBCS seems to be affected by the type of bariatric procedure. There could be a few reasons for this finding. RYGB has been previously one of the most frequently performed bariatric procedures worldwide (Angrisani et al., 2018). Further, numerous studies have been reported a significantly higher reduction in body weight after RYGB than after SG (Lee et al., 2019; Melissas et al., 2017).

The desire for BCS after MWL has been consistently reported. Many studies have shown that up to 85% of patients desiring BCS at one or more body sites after MWL (Mitchell et al., 2008; Sioka et al., 2015). According to a Finnish study, only 15.5% of bariatric patients did not desire any post-bariatric plastic surgery procedure (Giordano et al., 2014). More than six months after BS, patients were more likely to desire BCS than those with a shorter time since BS (Al-Hadithy et al., 2013). The relatively high numbers of patients desiring BCS are most likely due to significant functional and psychological problems caused by redundant skin after MWL. Despite the desire for BCS, actualized numbers are much lower. Typically, only 6–25% of patients undergo any BCS after MWL (Aldaqal et al., 2012; Kitzinger et al., 2012a; Klopper et al., 2014; Lazzati et al., 2018). In one earlier study, the prevalence of body contouring after RYGB was surprisingly high, 32% (Balaque et al., 2013). In this work, the prevalence of LBCS of 14.1% after BS is in line with previous studies.

The discrepancy between desire and realization of BCS might be attributed to unclear inclusion criteria for post-bariatric BCS or even patients' lack of awareness of the possibility of BCS after MWL. Therefore, there is a need for better communication between bariatric surgeons, plastic surgeons, and patients. One survey reported that only half of the bariatric surgeons report routinely discussing the likely negative physiological and psychological impact of hanging skin with their patients.

In many countries, socioeconomic status plays an important role in the decision to have BCS after MWL (Zammerilla et al., 2014). The rate of BCS is influenced by reimbursement policies of health insurance companies. BCS may be associated with cosmetic surgery, and for this reason, most insurance companies refuse to pay for post-bariatric surgery, even though the insurance covers weight loss procedures (Felberbauer et al., 2015). This might lead to unequal treatment of patients according to their economic situation. However, insurance is not the only limiting factor. In a previous study, only 14.9% of post-bariatric patients reported choosing to undergo plastic surgery despite having free access (Reiffel et al., 2013). Interestingly, here in Finland, we seem to have the same discrepancy between desire and actual prevalence. In Finland, public health care covers the cost of LBCS after MWL in case of functional problems due to excess skin.

One explanation for the considerable imbalance between the number of patients desiring BCS and those actually receiving BCS after MWL could be a fear of complications in further procedures. The complication rate is relatively high after LBCS. Up to 39% of females and 14% of males reported concerns about the occurrence of complications in BCS (Kitzinger et al., 2012a). In another study, 58% of post-bariatric patients expressed fear of complications, and 59.4% required additional information about the body contouring procedures (Aldaqal et al., 2012).

7.4. PREGNANCY AND DELIVERY AFTER LOWER BODY CONTOURING SURGERY

The safety of pregnancy and delivery is an important issue. Currently, there is a lack of evidence of whether the pregnancy is safe for the mother and unborn baby in the case of preceding LBCS. The plans for future pregnancy are considered a contraindication for LBCS, and women are advised to wait until their family size is complete before considering any LBCS (Borman 2002, Nahas 2002). However, pregnancy involves a slow and progressive tissue expansion, and muscles are contractile tissues and tend to return to their original size after pregnancy. The tightening of the abdominal muscle wall, specifically rectus plication for divarication, is one of the main issues under consideration, as there is a worry, it may affect the elasticity of the abdominal musculature during pregnancy (Menz 1996, Nahas et al., 2011). A further issue for pregnancy after LBCS is that pregnancy may damage the aesthetic result of the operation. In the past, abdominoplasty, especially rectus plication, was deemed hazardous to the unborn baby, and even termination of the pregnancy was recommended (Nahas et al., 2019). Currently, no guidelines, general treatment recommendations, or even data on the outcome of the mother and baby for patients who become pregnant after LBCS exist.

Study II aimed to determine whether pregnancy after LBCS is safe for the mother and baby. There is a paucity of data regarding the safety of pregnancy and delivery after LBCS. Women with preceding LBCS appeared to be older and had higher BMI in early pregnancy than all pregnancies and deliveries in Finland during the study period. Women with preceding LBCS also had more miscarriages. According to previous studies, both body mass index and age are important and independent risk factors for miscarriages (Magnus et al., 2019; Metwally et al., 2008).

7.5. PREGNANCY AFTER BARIATRIC SURGERY

Obesity in women of childbearing age has increased worldwide over recent decades (Carreau et al., 2017; Gimenes et al., 2017). More patients undergoing BS are fertile-aged women (Johansson et al., 2015; Kjaer et al., 2013). Probably for that reason, pregnancy after BS is a topic of active research. Many published studies have reported BS has an overall positive effect on maternal and neonatal outcomes by reducing the risk of GDM, hypertensive disorders, maternal complications during delivery, foetal macrosomia, and preterm delivery (Balestrin et al., 2019; Carreau et al., 2017; Yau et al., 2017). The positive impact of BS on female reproduction has also been confirmed (Falcone et al., 2018). However, BS appears to increase the risk of Caesarean and instrumental delivery (Stephansson et al., 2018). Nutritional disorders and anaemia resulting from BS have been shown to affect foetal growth and to cause an increased incidence of babies who are small for gestational age (Shawe et al., 2019). Women are advised to have a latency of at least 12 months, but preferably two years before pregnancy after BS (Narayanan et al., 2016; Parent et al., 2017). The first 12–16 months after BS is a period of rapid weight loss and metabolic changes that can potentially lead to nutritional deficiencies (Ciangura et al., 2019; Stein et al., 2014).

The data in **Study II** were further analysed by dividing patients into two groups depending on whether there had been any bariatric procedure before the LBCS. The bariatric group comprised 26 women (28.3%) and the non-bariatric group 66 women (71.7%). Most women, 84.6%, in the bariatric group underwent gastric bypass operation. Women with preceding BS were older ($p = .025$) and had a higher mean BMI in early pregnancy ($p < .001$) than women with no preceding BS.

According to previous studies, the BS presents a higher risk for small-gestational-age babies and shorter gestation time (Carreau et al., 2017; Johansson et al., 2015; Kjaer et al., 2013). However, there was no significant difference in the duration of pregnancy, the number of babies with low birth weight or the number of preterm deliveries.

In line with previous studies on the health benefits of BS, the analysis of the pre-delivery diagnosis revealed that gestational diabetes ($p<.001$) and excessive foetal growth cumulated in the non-bariatric group, even though the early pregnancy BMI was significantly higher in the bariatric group (Aricha-Tamir et al., 2012; Lesco et al. 2012; Balestrin et al., 2019). Bariatric procedures are most commonly laparoscopic with limited incisions and thus do not alter the abdominal wall. The issues with pregnancies and babies are more related to nutrition.

The latency between LBCS and pregnancy

The latency between LBCS and pregnancy did not have any effect on the risk for low birth weight, preterm delivery, or Caesarean section. Thus, no cut-off points for latency between LBCS and pregnancy emerged. The wound healing and scar maturation are systematic, that cicatrisation is usually finished one year after any surgery procedures (Bond et al., 2008). Therefore, based on the physiology of wound healing, a latency of 12 months between LBCS and pregnancies should be advised. However, in any pregnancy following long-incision LBCS, substantial stretching and tissue expansion occurs only in the latter two trimesters. The amount of tension on the scars in the first trimester is minimal to non-existent. Therefore, a period of six months following LBCS translates to at least nine months before any worry of significant stretching. Regarding rectus plication and pregnancy, generally, at least three months after rectus plication operation, any core exercises are allowed, as the midline rectus plication scar improves over time. According to the Swedish National Guidelines, the last two years should pass since last childbirth before considering rectus plication surgery, and pregnancy after that should not be planned (Carlstedt et al., 2020).

Length of pregnancy after LBCS

The length of pregnancy is somewhat shorter among women with preceding LBCS (p =.009). However, these pregnancies proceed to term, and the mean length is only shorter by 3.6 days. Focusing on first pregnancies and deliveries after LBCS, it was verified that these pregnancies proceed to term, even though the length of pregnancy is shorter and there is an overrepresentation of pre-term deliveries (<37 weeks) (p <.001). These pre-term deliveries occur near term (late pre-term). The overrepresentation of pre-term deliveries after LBCS might be described by maternal demographics rather than by an association with preceding LBCS. The mothers in the LBCS group were heavier and older. As **Study II** was observational, it cannot provide a clear rationale for this conclusion, and thus further studies are warranted.

Deliveries after LBCS

Study II revealed a significant difference in planned Caesarean sections in the LBCS group compared with all deliveries (16.4% vs 6.8%, p<.001). Subgroup analysis uncovered a high incidence of fear of childbirth and an extremely high incidence of previous Caesarean sections. These factors presumably explain the increased proportion of planned Caesarean sections (Nieminen et al., 2009, Handelzalts et al., 2012). An additional reason may be that the previous LBCS creates fear or worry in obstetricians. In **Study II**, as mentioned earlier, gestational diabetes and macrosomia were significantly more common in the non-bariatric group. Also, these women had more previous Caesarean sections. These factors are all important and independent indications for Caesarean sections and presumably explain the increased proportion of planned procedures (Kamana et al. 2015, Feghali et al., 2016, Gascho et al., 2017). The higher incidence of fear of childbirth results in operations on maternal request, which have no ICD code in Finland. However, no significant difference emerged in urgent Caesarean sections or emergency Caesarean sections. This finding suggests that previous LBCS is not contraindicated for vaginal delivery, and vaginal delivery is safe for this patient population.

Effect of LBCS on the unborn child

A higher proportion of low-birth-weight babies (<2500 g) in the LBCS group (7.4%) was found compared with total births in Finland (4.5%). However, this association did not prove statistically significant. An overrepresentation of low-birth-weight babies was recorded in the first deliveries in the LBCS group, 7.6% vs 4.4%, but this finding was insignificant.

Pregnancy and delivery are safe for mother and baby

This thesis verified in a comprehensive national registry-based study that pregnancy and delivery after LBCS are apparently safe for mother and baby. Patients of child-bearing age should be informed that pregnancies after LBCS most often proceed to term, but the risk for pre-term delivery and a low-birth-weight baby is increased, especially after earlier BS. There is also an increased risk of Caesarean section, probably due to patient history. These procedures are more likely to be planned. Longer latency between the LBCS and pregnancy does not decrease the risks. According to this thesis, pregnancy and delivery appear to be safe for the mother and baby. However, based on these results, the possible deviations from normal pregnancy and delivery should be discussed with fertile-aged women seeking LBCS. No maternal or infant mortality occurred.

Rectus plication for muscle divarication in conjunction with LBCS may affect the elasticity of the abdominal musculature during pregnancy. Another shortcoming is that based on national register data, there is no data if the rectus muscles were plicated during the LBCS. There is no specific ICD-10 or NSCP code for rectus diastasis or code for the plication operation. However, in **Study II**, the diagnosis "Ventral hernia without obstruction or gangrene (K43.9)" is prevalent and statistically overrepresented in the non-bariatric group. This diagnosis is commonly used for rectus diastasis. Due to the lack of a specific diagnosis code, this notion remains purely speculative. Rectus plication techniques vary, from single sutures to mesh reinforcement in the midline (Emanuelsson et al., 2016; Mommers et al., 2017). Furthermore, most studies of rectus plication have been done on postpartum women (Emanuelsson et al., 2016; Olsson et al., 2019; van Uchelen et al., 2001). Therefore, rectus plication could not be considered a style factor compromising pregnancy after LBCS.

To conclude, this thesis provided data that can be instrumentalized to inform fertile-aged women seeking LBCS. Nevertheless, possible deviations from normal pregnancy and delivery should be discussed with fertile-aged women seeking LBCS.

7.6. COMPLICATIONS AFTER LOWER BODY CONTOURING SURGERY

Post-operative complications are an important measure when comparing surgical outcomes and quality. Using a well-defined classification for reporting complications is to eliminate subjective analysis of severe adverse trials and any underestimation of seriousness that leads to decline complications. There is no consensus on how to define complications after post-bariatric BCS. For example, there is currently no specified width or length of wound separation after the operation that constitutes wound dehiscence; hence, reporting this complication is fundamentally subjective in nature. Skin necrosis is often associated with wound dehiscence as well.

Furthermore, necrosis and wound dehiscence should be reported separately. In addition, the variable reports of "necrosis" lead to questioning the types of necrosis since necrosis could refer to either skin necrosis or soft tissue necrosis. Some clinics may also report all complications, while others only report those that they consider major complications.

Study III used the Clavien-Dindo classification, which was initially published in 1992 and updated in 2004. The Clavien-Dindo classification has been used progressively in clinical practice and clinical trials concerning surgical procedures because it is simple, reproducible, and adaptable (Clavien et al., 2009). However, only a few recently published studies have applied a systemic approach, including the Clavien-Dindo classification, to categorize post-operative complications (Giordano et al., 2020; Morandi et al., 2019; Poodt et al., 2016; Rosa et al., 2019b; Swedenhammar et al., 2018; van der Beek et al., 2011).

Numerous studies have clearly established that BCS after MWL is related to the high frequency of post-operative complications (Dutot et al., 2018; van der Beek et al., 2011; Vidal et al., 2017). Although body contouring procedures are associated with increasing QoL and high patient satisfaction, the relatively high post-operative complication rate may negatively affect these potential benefits (Montemurro et al., 2015, Beidas et al., 2018, Schlosshauer et al., 2021). Presumably, the high complication rate could be one reason for the low prevalence of LBCS among patients who have undergone BS.

Patient selection for lower body contouring surgery

An appropriate patient pre-operative evaluation for LBCS is an important factor in controlling post-operative complications and remains the essential factor in achieving satisfactory outcomes while minimizing morbidity. In the literature, risk factors for post-operative complications include age, gender, and the total amount of weight loss (Chong et al., 2012; Greco et al., 2008).

Pre-operative BMI over 30 kg/m^2 has been found to increase the risk of any post-operative complications, including wound healing problems, infections, seromas, haematomas, and VTE (Au et al., 2008; Coon et al., 2009; Greco et al., 2008). In addition, smoking (Agha-Mohammadi et al., 2008; Momeni et al., 2009), co-morbidities, especially T2DM and hypertension (Winocour et al., 2015), and nutritional deficiencies (Agha-Mohammadi et al., 2008) have been reported to increase the incidence of complications. Deficient outcomes of BCS after MWL can also be linked to the weight loss method. Patients with preceding BS have a 60-87% increased risk of complications after BCS compared with non-bariatric patients who have lost weight by lifestyle changes (Hasanbegovic et al., 2014).

Study III included 158 patients with MWL who underwent LBCS, either abdominoplasty or body lift, between 2009 and 2015. Ninety-six complications were recorded in 80 patients, with an overall postoperative complication rate of 51%, which agrees with literature reporting complication rates fluctuating from 28% to 78% (Garcia-Garcia et al., 2014; Guest et al., 2017; Parvizi et al., 2015). The majority, 80.2%, of complications were minor (grades 1 and 2) according to the Clavien–Dindo classification. No deaths or life-threatening complications, such as VTE or PE were recorded. Further, most patients had only one complication. More than 75% of all complications were classified as late, that is, occurring 7 to 30 days post-operatively. Only 8.3% of all complications occurred during the first 24 hours after the operation.

The most common recorded complications were infection-related, including superficial wound infections (18.8%) and deep tissue infection (13.5%), followed by seromas (23.9%) and haematoma/bleeding (22.9%). These findings are in line with earlier studies, where the most common post-operative complications following LBCS were seromas, followed by wound-related problems, including dehiscence and skin edge necrosis (Botero et al.,2017; Kitzinger et al., 2012a; Losco et al., 2020). Other post-operative complications include haematomas, VTE, PE, lymphoedema, and nerve injuries (Ducic et al., 2014; Montano-Pedroso et al., 2016; Wes et al., 2015).

Suture extrusion or fistula are also common after post-bariatric BCS. Twelve suture fistulas (12.5% of all complications) were recorded in **Study III.** Suture fistulas were hardly ever reported as a complication in the literature. However, sometimes these may be defined as minor complications when management includes observation and suture removal. When comparing abdominoplasty with a body lift, no significant difference in wound healing complications was found.

Risk factors

In **Study III,** no statistical difference in complication rates emerged when comparing bariatric and non-bariatric patients. This finding contradicts previous studies. Older age ($p = .042$) at operation was associated with an increased risk for immediate haematoma or bleeding requiring surgery. Among early complications, high maximum lifetime weight ($p = .035$) and high pre-operative weight ($p = .0053$) were significantly correlated with a haematoma or bleeding requiring surgery.

Approximately half of MWL patients suffer from nutritional deficiencies, not limited to those individuals undergoing malabsorptive procedures (Agha-Mohammed et al., 2008a). Post-bariatric patients often have folate, vitamin B-12, and iron deficiencies (Via et al., 2017). Similarly, total protein intake is reduced after BS due to changes in dietary habits (Laurenius et al., 2013). It is largely known that nutrition and proteins profoundly influence the process of wound healing and angiogenesis (Albino et al., 2009; Wild et al., 2010). Nutritional deficiencies must be taken into account when considering LBCS after MWL. It should be carefully weighed whether patients undergoing LBCS would benefit from a treatment of multivitamins, iron and calcium supplements before surgery. If there is concern about protein or nutrient deficiencies, the patient should be referred to the bariatric nutritional team for further evaluation and treatment to correct the deficiencies. Because LBCS is often haemorrhagic, anaemia should be detected and corrected pre-operatively.

There is significant evidence of the damaging effect of smoking on the post-operative outcome (Pluvy et al., 2015; Theocharidis et al., 2018). For this reason, smoking cessation must be actively encouraged in pre-operative assessment and even required before LBCS. Despite the best intentions, most patients are not forthcoming with the whole truth and may compromise abstinence. Objective evidence of the patient's smoking history may only be possible through the introduction of compulsory urine nicotine testing at the pre-admission clinic or prior to the operation. It would enable not only health care cost savings in post-operative care but also minimize morbidity in delayed wound healing and other complications. The routine use of the continuity test in a pre-operative setting might significantly reduce the risk of delayed healing and other serious complications.

Re-operation due to complications

In **Study I,** secondary operations after abdominoplasty or body lift were recorded from the Finnish national health registers according to surgical procedure codes. A re-operation was required in 2.8% of cases. Only one in-hospital death (0.1%) was recorded within one month of abdominoplasty. In **Study III,** altogether 14.6% of all complications needed surgical intervention.

7.7. MUSCLE STRENGTH AFTER MASSIVE WEIGHT LOSS

The aim of **Study IV** was to evaluate the muscle strength of MWL patients who had redundant extra skin around the lower body and desired LBCS. Altogether 23 patients who met the criteria for LBCS were recruited.

Sarcopenic obesity

Sarcopenia is common among elderly adults, but it can also occur earlier in life (Kim et al., 2015). Sarcopenic obesity is the term used to describe the condition involving both low muscle mass and high body fat (Baumgartner 2000, Cruz-Jentoft et al., 2019)). Obesity is a risk factor for the development of knee osteoarthritis by different mechanisms, resulting in activity limitation, pain, and exercise restrictions in general. Some studies have clearly indicated that muscle weakness, low skeletal muscle mass, or sarcopenia occurs in conjunction with obesity in lower extremity osteoarthritis (Godziuk et al., 2018; King et al., 2016). MWL through gastric bypass surgery results in decreases in dynamic and peripheral static muscle strength and no improvement in aerobic capacity (Stegen et al., 2011).

The three fitness tests in **Study IV** were selected because each of these has previously been shown to have acceptable reliability and all three tests have age- and gender-related classification. The test results of each participant were compared to the age-and-gender reference values. Hand grip strength is a significant predictor of health, muscular durability, capacity, and overall strength (Bobos et al., 2019; Bohannon, 2008). Hand grip strength test is used to diagnose sarcopenia, frailty, and undernutrition, and it is the simplest method for assessing muscle function in clinical practice (Fielding et al., 2011; Sousa-Santos et al., 2017). The weak hand grip level is linked to various health outcomes, including higher all-cause mortality rates and morbidity (Leong et al., 2015; Sayer et al., 2015). The low hand grip level is a reliable clinical marker of poor mobility and a better predictor of clinical outcomes than low muscle mass (Lauretani et al., 2003).

Fitness test results

Nearly 90% of participants received worse-than-average hand grip strength test results, and only 8.7% attained an above-average level. There was a noticeable difference in the mean results between bariatric and non-bariatric participants (27.6 vs 36 kg). However, due to the small number of participants, no statistical analysis was conducted in **Study IV**.

The results from the dynamic muscle strength of the body test and the squat test were somewhat better than those from the hand grip strength test. In the former test, up to 22% of participants reached the highest scores, although more than half settled at the below-average level. In the squat test, nearly 74% of participants reached at least an average and 26% below-average level. The results of the squat test are better than those of either the hand grip strength test or the dynamic muscle strength of the body test. Muscle strength in the lower extremities is greater than upper body muscle strength, probably due to patients' previous obesity. Obese patients carry their massive body weight on the lower extremities, making the muscles stronger.

The participants who lost weight without BS seemed to have better results in all three fitness tests. One explanation might be that usually, lifestyle changes include some sort of physical activity. However, little is known about individuals who lose massive weight by lifestyle changes. The malabsorptive characteristic of the BS and the poor protein intake during massive weight loss induce skeletal muscle atrophy, with a concomitant decrease in muscle strength (Bernert et al., 2007).

Sarcopenia and reduced muscle function are associated with post-operative complications, including infections and wound healing problems (Lieffers et al., 2012). The results of **Study IV** may partly explain the high post-operative complication rate. Further research is needed to verify our assumption.

The sample size was modest and larger studies are required to substantiate these results. Moreover, most participants in this study had undergone BS, and a larger cohort will enable investigation of the effect of the weight loss method on muscle strength.

Exercise and nutrition are the two key interventions in the management of sarcopenic obesity. It has been shown that exercise alone or combined with supplementation decreased fat mass and increased total skeletal muscle (Hsu et al., 2019). Further studies would benefit from more specific measurements of the different approaches to weight loss, including caloric restriction, daily exercise, pre- and post-exercise behaviours before weight loss, medications, or combinations of these. The level of fitness before MWL in **Study IV** is unknown. Therefore, it is also unknown whether obesity duration or total duration of weight loss caused poor fitness test results. The level of aerobic fitness was not tested in our study. However, a professional physiotherapist performed all three fitness tests systematically, and the results were compared with existing age- and gender-matched levels.

Based on the results of **Study IV**, patients with MWL have remarkably low muscle strength compared with the average population. Especially the hand grip strength results are clearly below-average levels. Further, our results suggest that BS may lead to even lower muscle strength compared with weight loss by lifestyle change. A previous study demonstrated that nearly half of the post-bariatric patients declared avoiding some physical activities or sports due to excess skin (Baillot et al., 2013). Future prospective research should evaluate whether BCS improves muscle strength in these patients.

7.8. CENTRALIZATION AND MULTIDISCIPLINARY TEAM

Caring for patients with preceding MWL involves awareness of the physiological issues relevant to this patient population. Despite the significant weight loss, many of these patients remain within the obese range, with BMI greater than 30 kg/m^2, and have associated medical issues, including co-morbidities, nutritional deficiencies, and psychological issues (Aarts et al., 2017). Plastic surgeons attending to body contouring procedures after MWL should be aware that post-bariatric patients comprise an exclusive population because of the surgical manipulation of the gastrointestinal tract.

Large medical centres usually offer fully functioning multidisciplinary teams of specialists capable of tackling all aspects of the diseases. Care for obese patients is often organized by multidisciplinary teams (Abela et al., 2011). The typical members of this team include abdominal surgeons, endocrinologists, dietitians, nurse specialists, and psychiatrists. Plastic surgeons often have not been routinely involved in this multidisciplinary structure, despite most of the patients suffering from hanging excess skin after MWL.

A treatment plan covering both BS and concurrent recommendations to plastic surgeons might provide more comprehensive care for bariatric patients. The bariatric surgeon must be aware of and inform bariatric patients about potential redundant skin problems after MWL. A previous study evaluated patients after BS with a 34-question survey mailed to 1158 patients. The response rate was 24.5%. Altogether, 25.4% of bariatric patients reported discussing post-bariatric body contouring procedures with their bariatric surgeon perioperatively, 14.1% were described for plastic surgeon consultation, and only 11.6% underwent body contouring procedures. Even 39% of bariatric patients reported they might have chosen differently if they had received more information (Reiffer et al., 2013).

Klopper et al. provided in 2014 similar results; almost half (47.7%) of post-bariatric patients said they did not proceed with plastic surgery due to a lack of information regarding the possibilities. Further efforts are warranted towards improving patient and surgeon education regarding post-bariatric body contouring options are warranted. Another survey reported better results; up to 54% of bariatric surgeons described routinely discussing the likely negative physiological and psychological impact of hanging skin with their patients (Warner et al., 2009). In this same study, 51% of bariatric surgeons reported that patients who underwent BCS were overall more satisfied with their decision to undergo BS than bariatric patients who had not had body contouring.

Plastic surgeons must be familiar with a wide range of technical approaches to special types of BS and have the ability to handle the unique medical and psychological issues of MWL patients.

In this thesis, over half of the hospital districts appeared to have under 50 LBCS during 1998–2016 in Finland. The European Surgical Association (ESA) conducted a review of centralization for highly specialized surgeries (Vonlanthen et al., 2018). Centralization of BCS after MWL to highly specialized centres should be considered. Further, post-bariatric surgery evaluation should be a routine part of the multidisciplinary effort. Post-bariatric BCS is an important component of the total care for obesity, allowing optimization of the results achieved with BS. Patients after BS may have nutritional deficiencies, anaemia, or dumping syndrome. These patients should be referred with a small threshold for consultation with their bariatric surgeon or a nutritionist. Further assessment of body image and psychiatric co-morbidities should be performed to ensure there is no diagnosis of BDD. Centralization would also provide economic benefits in the long run.

This thesis also disclosed the uneven distribution of post-bariatric operations nationwide. One reason for this could be different criteria for LBCS. Until now, no clear national criteria for LBCS after MWL have existed in Finland, and every hospital has had its own criteria. The solution for this discrepancy is uniform criteria for LBCS for patients who have had a bariatric operation. Optimal management guidelines have an impact on the complication rate and patients' outcomes.

8 RECOMMENDATIONS AND FUTURE PERSPECTIVES

Currently, there is no field in plastic surgery growing more rapidly than BCS after MWL. Worldwide, obesity continues to rise, followed by an increasing number of bariatric procedures.

Updated guidelines for BCS after MWL in Finland are missing. This thesis has shown that the prevalence of LBCS has risen in Finland in the last decades. National guidelines would ensure standardization of treatments throughout the country and the supply of safe and improved patient care. A further goal of guidelines is to enable the national data collection for research and outcome studies (Soldin et al., 2014). A previous Swedish study reported that the rate of early complications after abdominoplasty for MWL could be significantly reduced with improved surgical experience and standardised management guidelines (Swedenhammar et al., 2018).

It is important that the patient is well-informed about the possibilities and limitations of plastic surgery before undergoing post-bariatric surgery to limit high and often unrealistic expectations of BCS. Nowadays, the internet represents one of the most important sources of information for patients and doctors. It is widely assumed that post-bariatric patients are motivated to source data on the different types of operations available to reshape and remodel their bodies, thus returning to functional and physical wellness and increasing their QoL. However, lo Torto et al. discovered in 2020 a critical lack of information on the internet about qualitative risks and potential complications of the most commonly performed post-bariatric procedures worldwide. In view of the many risks and benefits associated with post-bariatric BCS, surgeons should aspire to improve their communication with patients considering contouring surgery.

Centralization of BCS to highly specialized centres should be carefully considered (Kuo et al., 2015, Khan et al., 2016). Both national criteria for BCS and centralization would yield better surgical outcomes and economic benefits (Swedenhammer et al., 2018)

Alternative contouring options to full abdominoplasty should be provided for fertile-aged women. Liposuction of the abdomen and the lower trunk could be an alternative when considering body contouring for fertile-aged women since it does not modify the abdominal muscle wall or significantly alter the elasticity of the skin fat envelope, which could cause issues during subsequent pregnancies. However, liposuction does not improve the appearance of excess skin due to MWL. Liposuction might usually be only an adjunct and not be a substitute for direct surgical excision.

This thesis suggests that BS may lead to even lower muscle strength than weight loss by lifestyle changes. Future prospective research should evaluate whether BCS improves muscle strength in these patients.

9 STUDY STRENGTHS AND LIMITATIONS

Studies I and **II** are register-based studies and might be limited by the validity of the National Hospital Discharge Register (Sund et al., 2012). The Finnish Government maintains data from the National Hospital Discharge Register. The Register collects data on the activities of health centres, hospitals, and other institutions providing inpatient care for the purposes of statistics, research, and planning. The register includes basic data on the service provider, patient, and treatment received by the patient, e.g., diagnoses, surgical procedures, interventions and discharge from care. The data include no freehand text from patient files on indications or decisions for specific operations or procedures.

Register-based studies have some limitations that must be addressed. When using data from registers for research purposes, the research is limited to the variables included in the registers. Coded diagnoses are not the most relevant, and there may be variations in coding practices between persons, departments, or institutions. However, this does not compromise the value of data in this register being used in studies that are not feasible to conduct otherwise. Therefore, technical incompleteness does not cause bias in the results. The main strength of this thesis is using nationwide registries that allow reliable assessment of the incidence and outcome of LBCS in a large population of bariatric patients in both public and private hospitals.

In **Study III,** the low number of patients and the drawbacks inherent to retrospective studies can be regarded as the main limitations. In addition, it was a single-centre retrospective analysis. Reviewing clinical diagnostic impressions from medical records not intended for research work is prone to investigator bias. Strengths of this study include comparable bariatric and non-bariatric groups and comprehensive recording of complications. However, this study did not record important parameters, including pre-operative nutrition status and haemoglobin level, length of operation, and hypothermia, which can be relevant for the development of complications.

In **Study IV,** the sample size was modest and larger studies are required to substantiate these results. Moreover, most participants in the study had undergone bariatric surgery, and a larger cohort will enable investigation of the effect of the weight loss method on muscle strength. Further studies would benefit from more specific measurements of the different weight loss routes, including caloric restriction daily exercise, pre- and post-exercise habits before weight loss, medications, or combinations of these. The level of fitness before MWL in these patients is unknown. Therefore, it is also unknown whether obesity duration or total duration of weight loss caused poor fitness test results. The level of aerobic fitness was not tested in **Study IV**. However, all three fitness tests were performed systematically by a professional physiotherapist, and the results were compared with existing age- and gender-matched levels.

10 CONCLUSIONS

I Only 14.1% of patients who underwent BS received subsequent LBCS. There is a strong correlation between bariatric surgery and two-year latency for LBCS.

II Pregnancy and delivery after LBCS are safe for the mother and child. Women of child-bearing age should be informed that pregnancies after LBCS most often proceed to term, but the risk for pre-term delivery and a low-birth-weight baby is increased, especially after the previous BS.

III Post-operative complications following LBCS due to MWL frequently occur, although most are minor and not life-threatening. The risks for LBCS following MWL should be considered individually.

IV Patients with preceding MWL have lower muscle strength than the age- and gender-matched normal population. Especially the results of the hand grip strength test were considerably worse.

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