Physical activity among patients undergoing bariatric surgery

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To Johan, Noah and Filip, my family

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ABSTRACT

The World Health Organization (WHO) recommend that adults should perform ≥150 minutes of moderate intensity physical activity or ≥75 minutes of vigorous intensity physical activity or an equivalent combination of them during the week. The WHO further recommends muscle-strengthening activities, to be performed two or more days per week. It is known that physical activity improves health and reduces the incidence of several diseases.

Obesity is a major global health problem and currently leads to more deaths worldwide than underweight. Obesity is associated with a sedentary lifestyle, which has a negative effect on health. People with obesity can achieve significant improvements in health by performing the recommended dose of physical activity. Weight loss surgery is now a common treatment of obesity and is associated with greater long-term weight loss than conventional treatment. Today, there is a lack of knowledge about different aspects of physical activity among patients undergoing bariatric surgery.

The overall aim of this thesis was to study different aspects of physical activity among patients before and one year after bariatric surgery.

This thesis includes two qualitative studies (Paper I and II) aiming to describe how patients with obesity experience physical activity before and one year after bariatric surgery. In Paper III, the accuracy of a pedometer (Silva pedometer, model 56013-3) and an accelerometer (Silva Ex3 plus, model 56026), when used by women with obesity, were investigated. In Paper IV, the physical fitness and physical activity level of women before and one year after bariatric surgery was investigated.

Paper I and II
Several obstacles influence the capacity and willingness of patients to be physically active, both before and one year after surgery. The perceived obstacles are often related to excess weight, excess skin or feeling uncomfortable when appearing in public. Both before and one year after bariatric surgery, support is of importance to initiate, find and maintain a suitable physical activity level.

Paper III
The accelerometer was found to provide accurate step count readings when it was hung around the neck, while the pedometer was found to be inaccurate as a major problem with undercounting was identified. The accelerometer is therefore suitable for use in studies and for health promotion strategies for obese women.

Paper IV
The physical activity level increased in this group of women one year after bariatric surgery, compared to before surgery. Distance walked in 6 minutes and muscular endurance also increased, and grip strength was preserved. These improvements and the considerable weight loss that these women underwent are important factors in reducing the risk of developing lifestyle-associated diseases and risk of premature death in this group.

Although the physical activity level was found to be increased one year after surgery, some individuals still need and want help in order to increase their physical activity level up to the recommended level. Personalized guidance and training provided by a physiotherapist may lead to an increased understanding of the positive benefits and an increased level of physical activity among the patients, so that they reach the recommended level.

Keywords: Accelerometer, bariatric surgery, cardiovascular endurance, motor activity, muscular endurance, muscular strength, obesity, pedometer, physiotherapy, physical fitness, physical activity

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SAMMANFATTNING PÅ SVENSKA

Världshälsoorganisationen (WHO) rekommenderar alla vuxna att vara fysiskt aktiva mer än 150 minuter i veckan. Intensiteten bör vara minst måttlig. Vid hög intensitet rekommenderas mer än 75 minuter per vecka. Aktivitet av måttlig och hög intensitet kan även kombineras och bör spridas ut över flera av veckans dagar i pass om minst 10 minuter. Muskelstärkande fysisk aktivitet, som t.ex. styrketräning bör också utföras minst 2 gånger per vecka. Det är känt att fysisk aktivitet förbättrar hälsan och minskar förekomsten av flera sjukdomar.

Fetma och övervikt orsakar globalt mycket stora hälsoproblem och för närvarande leder fetma till fler dödsfall i världen än svält. Fetma är associerad med en stillasittande livsstil, vilket har en negativ inverkan på hälsan. Personer med fetma kan dock uppnå betydande förbättringar i hälsa genom att utföra den rekommenderade dosen av fysisk aktivitet. Viktminskningskirurgi är numera en vanlig behandling av fetma och den är förknippad med större långsiktig viktminskning än konventionell behandling. Idag saknas information om olika aspekter av fysisk aktivitet innan och ett år efter viktminskningskirurgi.

Det övergripande syftet med denna avhandling var att studera olika aspekter av fysisk aktivitet hos patienter innan och ett år efter viktminskningskirurgi.

Avhandlingen inkluderar två kvalitativa intervjustudier (Studie I och II) med syfte att undersöka hur patienter med fetma upplever fysisk aktivitet innan respektive ett år efter viktminskningskirurgi. I Studie III undersöktes hur korrekt en stegräknare (Silva stegräknare, modell 56 013-3) och en accelerometer (Silva Ex3 plus, modell 56 026) mäter steg hos kvinnor som lider av fetma. I Studie IV, undersöktes om/hur mycket gångförmågan på 6 minuter, muskeluthålligheten, greppstyrkan samt tiden i fysisk aktivitet förändrats ett år efter, jämfört med innan, viktminskningskirurgin.

Patienter upplever många hinder som minskar deras förmåga och vilja att vara fysiskt aktiva, både före, och ett år efter, viktminskningskirurgin. De upplevda hindren är ofta relaterade till övervikt, överskottshud eller obehag inför att visa sig offentligt i bad-/träningskläder. Både före och ett år efter viktminskningskirurgin upplevde patienterna att stöd är av betydelse för att initiera och upprätthålla en lämplig fysisk aktivitetsnivå.

Accelerometern registrerade antal steg korrekt när den hängde runt halsen. Stegräknaren visade sig däremot i hög grad underskatta antalet steg. Accelerometern är därför lämplig för användning i studier och för hälsofrämjande strategier för kvinnor som lider av fetma.

Jämfört med före operationen ökade den fysiska aktivitetsnivån, gångsträckan på 6 minuter samt muskeluthålligheten på gruppnivå hos kvinnorna, ett år efter viktminskningskirurgin. Dessa förbättringar och den betydande viktminskningen är viktiga faktorer för att minska risken för att utveckla livsstilssjukdomar och därmed risken för förtida död i denna grupp av kvinnor.

Även om den fysiska aktivitetsnivån ökade på gruppnivå ett år efter operationen, behöver och önskar vissa individer öka sin fysiska aktivitetsnivå till den av WHO rekommenderade nivån. En personlig vägledning och vid behov en anpassad träning hos en sjukgymnast skulle kunna leda till en ökad förståelse för de positiva effekterna av fysisk aktivitet. Det skulle dessutom kunna leda till att patienterna ökar sin fysiska aktivitetsnivå upp till den rekommenderade nivån.

LIST OF PAPERS

This thesis is based on the following studies, which are referred to in the text by their Roman numerals.

I. Wiklund M, Fagevik Olsén M, Willén C. Physical activity as viewed by adults with severe obesity, awaiting gastric bypass surgery. Physiother Res Int 2011;16:179-86.

II. Wiklund M, Fagevik Olsén M, Olbers T, Willén C. Experiences of physical activity one year after bariatric surgery. Submitted.

III. Wiklund M, Cider Å, Fagevik Olsén M. Accuracy of a pedometer and an accelerometer in women with obesity. The Open Obesity Journal 2012;4:11-7.

IV. Wiklund M, Fagevik Olsén M, Olbers T, Cider Å. Physical fitness and physical activity in Swedish women before and one year after Roux-en-Y Gastric Bypass surgery. Submitted.

CONTENT

ABBREVIATIONS

ADP	Air-Displacement Plethysmography
BMI	Body Mass Index
CVD	Cardiovascular Disease
DEXA	Dual-Energy X-ray Absorptiometry
FFM	Fat Free Mass
IPAQ	International Physical Activity Questionnaire
LDS	Laparoscopic Biliopancreatic diversion with duodenal switch
LRYGB	Laparoscopic Roux-en-Y gastric bypass
MET	Metabolic equivalent
VLCD	Very-low-calorie diet
VO_{2max}	Maximum oxygen uptake
WCPT	World Confederation for Physical Therapy
WHR	Waist-hip ratio
WHO	World Health Organization
6MWD	Six-Minute Walk Distance
6MWT	Six-Minute Walk Test

1 INTRODUCTION

1.1 Physiotherapy

Physiotherapy is the third largest health profession, after nurses and physicians, in both Sweden and the Western world. It is both a separate academic subject and professional field of work [(1)]. According to the World Confederation for Physical Therapy (WCPT) [(2)], physiotherapy provides services that enable people to develop, maintain and restore maximum movement and functional ability through life. This includes circumstances where function and movement are challenged, for example by ageing, injury, disorders, or environmental factors [(2)]. According to the First Physical Therapy Summit on Global Health [(3)] Physiotherapy is the primary health profession committed to noninvasive interventions, i.e. nondrug and nonsurgical interventions, including health education and exercise. Thus this profession is uniquely qualified to lead the fight against lifestyle-related conditions in the 21st century [(3)].

1.2 Physical activity and physical fitness

Physical activity is defined, by Caspersen et al [(4)], as *"any bodily movement, produced by skeletal muscles that result in energy expenditure"* and is therefore related to the movements that people perform. In contrast, physical fitness is a set of attributes that people have or achieve. Physical fitness can be described in terms of skill-related and health-related fitness [(4)]. Skill-related fitness is associated with motor skill performance or sport, and its components include speed, agility, balance, coordination, power, and reaction time [(5)]. Health-related fitness, on the other hand, has the following components: cardiorespiratory endurance, muscular endurance, muscular strength, body composition, and flexibility [(4)].

Physical activity and physical fitness are closely related since physical fitness is mainly determined by physical activity patterns over recent weeks or months. For most individuals, increases in physical activity produce increases in physical fitness, even if the amount of adaptation in fitness level to a standard exercise level varies widely and is under genetic control [(6-8)]. Definitions, related to physical activity and physical fitness, used in this thesis are described in *Table 1*.

Table 1. Definitions related to physical activity and physical fitness.

Body composition	The relative amounts of muscle, fat, bone, and other vital parts of the body [9].
Cardiorespiratory endurance	The ability of the circulatory and respiratory systems to supply fuel during sustained physical activity and to eliminate fatigue products after supplying fuel [9] .
Exercise	Planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness [4].
Flexibility	The range of motion available at a joint [9].
Light-intensity physical activity	Physical activity with an energy expenditure range of 1.6–2.9 METs [10].
Metabolic equivalent (MET)	One MET is defined as the energy expenditure for sitting quietly, which for the average adult is approximately 3.5 ml O_2* kg^{-1} *min^{-1} or 1 kcal * kg^{-1} * h^{-1} [11].
Moderate-intensity physical activity	Physical activity with an energy expenditure range of 3.0 to 5.9 METs [10].
Muscular endurance	The ability of muscle groups to exert external force for many repetitions of successive exertions [9].
Muscular strength	The amount of external force that a muscle can exert [9].
Physical activity	Any bodily movement, produced by skeletal muscles, that results in energy expenditure [4].
Physical fitness	A set of attributes that people have or achieve that relates to the ability to perform physical activity [4].
Sedentary behavior	Physical activity with an energy expenditure range of 1.0–1.5 METs [10].
Vigorous-intensity physical activity	Physical activity with energy expenditure at 6.0 or more METs [10].

1.2.1 Physical activity

Both the World Health Organization (WHO) [12] and the American College of Sports Medicine [13] recommend that adults aged 18–64 should perform ≥ 150 minutes of moderate intensity physical activity or ≥ 75 minutes of vigorous intensity physical activity, or an equivalent combination of them, every week. Physical activity should be performed in periods of at least 10 minutes duration. It is preferable to spread out the moderate/vigorous intensity physical activity on 5 or more days per week. Therefore it is important to encourage the integration of physical activity as part of daily lifestyle, for example by walking or cycling. Muscle-strengthening activities, such as resistance training, should involve major muscle groups and be performed on two or more days every week [12, 13].

Instead of expressing the volume of physical activity recommended in terms of minutes per week, it can be measured as kilocalories per week or metabolic equivalent (MET)-minutes per week. An energy expenditure of approximately 1000 kcal per week or 600 MET-minutes per week is consistent with the general recommendation [13].

Physical activity is associated with a marked decrease in cardiovascular disease (CVD) and all-cause mortality in both men and women, even after adjusting for other relevant risk factors [14]. Sufficient volume of physical activity has been shown not only to reduce the incidence of CVD, but also many other common lifestyle-related diseases such as type 2 diabetes mellitus, breast cancer, colon cancer, osteoporosis and depression [15]. Between 9-19% of all cancer cases in Europe could be attributed to lack of sufficient physical activity [16].

Research data also suggests that there is a dose–response relationship between physical activity and health outcomes, i.e. some activity is good, but more is better [17]. However, the slope of the dose–response curve is not clear, and it is likely that the shape of the curve may differ depending on the health outcome of interest and the baseline level of physical activity of the individual [17]. It is also the case that significant risk reductions for CVD and premature mortality have been observed at physical activity volumes below the recommended targets, starting at one-half of the recommended physical activity volume i.e. 500 kcal per week [18-21]. For example, half of the currently recommended volume of physical activity may be sufficient for significantly improving cardiorespiratory fitness in sedentary, overweight women [22].

It is known that sedentary behaviors are associated with negative health outcomes and that this association remains even after accounting for time spent in physical activity [23-25] Still, there are at present no recommendations concerning the amount of sedentary time that may be considered acceptable to maintain health and prevent illness. For example, Katzmaryzyk et al [23] found a dose–response association between sitting time and mortality from all causes and CVD, independent of time spent in physical activity. Consequently, the authors recommend that in addition to the promotion of moderate-to-vigorous physical activity and a healthy weight, patients should be discouraged from sitting for extended periods [23]. Dunstan et al [26] also found that there is a consistent independent association between sitting time/sedentary behaviors and elevated all-cause and CVD mortality risk [26]. As there are no definitive recommendations for how long people may sit or how frequently people should interrupt their sitting time, the general advice is currently to encourage people to limit their sitting and to avoid prolonged periods of sitting by standing or moving about [24].

Measuring physical activity

There are a number of available ways to measure physical activity. The doubly labeled water method is the criterion standard for energy expenditure assessment during free-living conditions. This method allows for the assessment of total energy expenditure, and it has been shown to provide valid estimates of daily expenditure. However, the high cost and complicated analyses limit the use of doubly labeled water in most large epidemiological studies [27].

Today there are highly advanced multisensory monitors on the market that can integrate motion data from a biaxial or triaxial accelerometer and physiologic metrics from skin temperature, galvanic skin response, and heat flux sensors to provide minute-by-minute estimates of energy expenditure [28]. However, due to their relatively high cost and intensive data management requirements, their use is typically limited to research. For clinical usage, step counting devices such as pedometers and accelerometers provide a more convenient way of objectively quantifying total daily activity. These devices are simple, inexpensive and often used in clinical practice and real world applications, as many people like to use them to monitor their physical activity level [29]. Even if pedometers are limited in the sense that factors such as speed, grade and duration of steps often cannot be determined, [13] they have been used to measure the level of physical activity and to increase motivation, thereby increasing the level of physical activity [30-32]. Pedometer-based walking programs have been shown to increase step counts and as a result give health benefits associated with both a modest decrease in weight and an increase in physical activity level [33]. Unfortunately, the accuracy of different brands of step counting devices used by individuals with obesity remains unclear, and previous studies have come to different conclusions [34-37]. Potential problems that affect accuracy include pedometer-tilt [35] and undercounting, so that it is possible that hundreds or even thousands of extra steps are taken before the pedometer indicates that the goal has been reached [38].

Physical activity questionnaires are often used for measuring physical activity but show limited reliability and validity. Nevertheless, questionnaires are valuable tools for indicating conditions where an increase in physical activity would be beneficial but also for monitoring changes in population activity [39].

1.2.2 Physical fitness

Physical fitness is a set of attributes that people have or achieve. The health-related components of physical fitness are cardiorespiratory endurance, muscular endurance, muscular strength, body composition, and flexibility [4]. In this thesis, tree of the health-related components are in focus: cardiorespiratory endurance, muscular strength and muscular endurance.

An increase in cardiorespiratory endurance will reduce the risk of early death, from any cause and from CVD in particular, and even small improvements are associated with a significant reduction in risk [40, 41]. The body adapts and improves cardiorespiratory endurance when an individual regularly engages in aerobic activities that involve large muscle groups, such as brisk walking, jogging, swimming, cycling, or rowing. To improve cardiorespiratory endurance, the American college of sports medicine recommends that individuals exercise aerobically ≥ 5 days per week at moderate intensity for 30-60 minutes or ≥ 3- 5 days per week at vigorous intensity for 20-60 minutes or a combination of these routines [13]. However, a greater improvement in maximal oxygen uptake (VO_{2max}) has been shown with vigorous-intensity physical activity, even when the duration of exercise is adjusted so that the same number of calories is expended [42]. Additional studies support these conclusions [43-45]. However, Swain [42] recommends that initially sedentary individuals aiming to improve their VO_{2max} should begin with moderate intensity physical activity and move up to higher intensities only after a period of adaptation (42) .

As previously described, muscle-strengthening activities such as resistance training, involving major muscle groups, should be performed two or more days in a week (12). The WHO further state (12) that individual adjustments may be needed, based on exercise capacity and specific health risks or limitations (12). The recommended level is equivalent to 8–10 exercises with 8–12 repetitions in 1-3 sets. Major muscle groups should be targeted and the weight or resistance should be high enough to cause local muscular fatigue at the end of each set (46). The American college of sports medicine (46) recommends that resistant training should include concentric, eccentric and isometric muscle actions. In addition, because all training adaptations are specific to the stimulus applied, and, because the human body adapts quickly to a resistance training program, at least some changes are needed in the training program in order for continual progression to occur. A relationship exists between increases in strength and local muscular endurance such that strength training alone may improve muscular endurance to a certain extent (46). Training, aimed at increasing local muscular endurance, implies that the individual performs a high number of repetitions i.e. long-duration sets with high muscle time under tension and/or minimizes recovery between sets (46).

Measuring physical fitness

At present there are several ways of measuring the different health-related components of physical fitness. Maximal oxygen uptake (VO_{2max}) is the criterion for measuring cardiorespiratory endurance (47). A measurement of VO_{2max} is achieved by analyzing expired air samples, collected while the individual performs an exercise of progressive intensity. Although maximal efforts must be used to measure VO_{2max}, submaximal tests can be used to estimate this value (48). No single test can be used to evaluate total body strength or muscular endurance. Muscular strength is always specific to a particular muscle or muscle group and refers to the maximal force, in Newton (N) or kilogram (Kg), that the muscle or muscle group can generate. Isometric or static strength can be measured using many devices, for example handgrip dynamometers. Dynamic strength can be assessed by measuring body movement against an external load. The simplest method of measuring dynamic strength involves various 1-repetition maximum weight-lifting tests, i.e. the heaviest weight that can be lifted once. Examples include bench press for the upper-body and leg press for the lower-body. Measurements of muscular endurance are often made with simple tests that measure the capacity of a muscle group to perform repeated contractions over a specific period of time, which should be enough to cause fatigue [(48)].

1.3 Obesity

Obesity is defined as abnormal or excessive body fat accumulation that impairs health [(49)]. Obesity and overweight are major global health problems, currently leading to more deaths worldwide than underweight. No less than 2.8 million adults die each year as a result of being overweight or obese, and these conditions are considered to be the fifth commonest cause of death [(50)]. The WHO estimates that in 2008 there were over 200 million men and nearly 300 million women with obesity in the world [(50)]. According to the WHO database [(51)], the 2010 global prevalence of overweight and obesity in the adult population, i.e. in people over 15 years, ranged from 3.7% in Ethiopia (women) and 3.5% in Eritrea (men) to > 90% in some small island nations in the Pacific Ocean (Nauru, Tonga). In Sweden, the prevalence of overweight and obesity was 47.2% of the women and 57.0% of the men [(51)].

The fundamental cause of obesity is an energy imbalance between calories consumed and calories expended. However, it is also a condition that becomes manifest more readily in people who have an inherited susceptibility to be in positive energy balance [(49)]. Bell et al [(52)] conclude that modern lifestyle has a key role in the current obesity epidemic, and that genes involved in human obesity really do exist [(52)]. Twin studies confirm that measures applied for general body fat, shape and composition in adults are strongly influenced by genetic factors [(53, 54)].

1.3.1 Body composition

In research different equipments are used to measure body composition. Dual-Energy X-ray Absorptiometry (DEXA) and Air-Displacement Plethysmography (ADP) are, for example, validated methods to examine Fat Free Mass (FFM) and they provide fast, accurate measures with little inconvenience for the patients [(55)]. DEXA measures fat mass, FFM, bone mineral content, bone mineral density, and provides estimates of the percentage of body fat [(56-58)]. In ADP, the human body volume is measured by letting a person sit inside an enclosed chamber (plethysmography), which displaces a volume of air equal to his or her body volume [59, 60]. Hydrostatic weighting is another method for determining body composition, but it requires expensive equipment and specifically trained personnel and can be quite time-consuming. Bioelectrical impedance is another way of assessing fat mass and FFM. A small electric current is passed throughout the body and the resistance encountered is measured [48]. Skinfold measures can be used to determine the amount of subcutaneous fat and can thereby be used to estimate body composition [48]. Skinfold measures are often technically difficult to perform in the severely obese and are limited by the lack of suitable reference standards, since most equations are developed for individuals of normal weight or overweight [61].

Body Mass Index

Body Mass Index (BMI) is defined as the weight in kilograms divided by the square of the height in meters (kg/m^2) [49]. It provides a useful population-level measure of overweight and obesity. BMI can be used to estimate prevalence of obesity within populations, as it is the same for both sexes and for all ages of adults. However, BMI should be considered a rough guide on the individual level due to its neglect of the relative contribution of different tissues such as muscle and fat [49]. The WHO defines overweight as a BMI ≥ 25 kg/m^2, and obesity as a BMI ≥ 30 kg/m^2. BMI classifications, according to the WHO [49], are shown in *Table 2.*

Table 2. BMI classifications.

	BMI (kg/m^2)	**Risk of comorbidities**
Underweight	< 18.5	Low (but risk of other clinical problems increased)
Normal range	18.5-24.9	Average
Overweight	25-29.9	Increased
Obesity class I	30-34.9	Moderate
Obesity class II	35-39.9	Severe
Obesity class III	> 40	Very severe

Waist and Hip circumference

Measuring waist and hip circumference is a simple and efficient technique for assessing body composition, since all you need is a measuring tape [62]. Waist circumference is unrelated to height, correlates closely with BMI and the ratio of waist-to hip circumference, and is also an approximate index of intra-abdominal fat mass and total body fat [63]. A moderate-to-high cardiorespiratory endurance is associated with a lower waist circumference for a given BMI, in both men and women, compared to those with low cardiorespiratory endurance. Therefore, it is suggested that measurement of waist circumference would substantially improve the ability to identify patients at health risk [64]. Waist circumference should be measured with the person standing with his or her weight evenly distributed on both feet and the feet about 25-30 cm apart. It should be measured in a horizontal plane, midway between the inferior margin of the ribs and the superior border of the iliac crest at the end of a normal expiration to the nearest 0.1 cm [65]. Hip circumference should be measured in a horizontal plane to the nearest 0.1 cm at the maximum extension of the buttocks with the person standing with his or her feet together and the arms at the side [65].

Waist-to-hip ratio (WHR) is calculated by dividing waist circumference by hip circumference, and, can provide additional valuable information about abdominal fat accumulation and carry important information for identifying middle-aged adults at increased risk of mortality [66]. Both waist circumference and WHR varies with sex and age and with ethnic differences. Therefore, cut-off points on disease risk, for example CVD, type 2 diabetes as well as mortality risk vary considerably between countries [67]. European cut-off points, i.e. an increased risk of metabolic complications are a waist circumference > 94 cm for men, and > 80 cm for women [68]. While European cut-off points for waist-to-hip ratio are > 0.95 in men and > 0.85 in women. Values over this have been shown to increase the risk of CVD , even among lean individuals [69].

1.3.2 Obesity related disease

Overweight and obesity have many health consequences and 44% of the diabetes burden, 23% of the ischemic heart disease burden and between 7% and 41% of certain cancer burdens are attributable to overweight and obesity [50]. Type II diabetes is a condition with a strong correlation to obesity [70], particularly to intra-abdominal fat accumulation [71-73]. Obesity predisposes to hypertension [70], high cholesterol [70], high triglycerides and impaired glucose tolerance, leading to increased incidence of CVD [49]. Research shows that obesity increases the risk of developing some cancer forms, including endometrial, colon, kidney, prostate and breast cancer [50, 74]. However, a recent meta-analysis showed that body mass index had no significant effect on the incidence of breast cancer during premenopausal period [75]. Obesity is also considered to increase the death risk for patients with colon, kidney, prostate, breast and endometrial cancer [76-79]. Other health problems associated with obesity are musculoskeletal problems, infertility, skin problems and respiratory difficulties, for example sleep apnea [49].

1.4 Weight loss

Weight loss implies a negative energy balance and involves strategies for reducing energy intake and increasing energy expenditure. A reduced caloric intake, as well as high levels of physical activity, are important predictors of long-term successful weight loss [80]. The American College of Sports Medicine [81] has concluded that weight maintenance seems to protect against an increase in chronic disease risk factors and that weight loss, even as little as 3% , can give positive changes in chronic disease risk factors [81]. In contrast a meta-analysis found no evidence that weight loss gave a survival benefit among healthy obese adults [82]. There are even examples of studies that indicate that weight loss increased mortality risk [83, 84]. For example, Allison et al [84] have found that weight loss was associated with increased mortality rate, while fat loss was associated with decreased mortality rate among individuals that were not severely obese [84].

Both fat mass and FFM decrease after weight loss [55, 85-89]. For bariatric surgical interventions, FFM loss varies from 12.7% to 52.7% of the weight loss [55]. A large loss of FFM is undesirable because non-adipose tissues are responsible for the majority of resting metabolic rate, regulation of core body temperature, preservation of skeletal integrity, and maintenance of function and quality of life as the body ages [90].

1.4.1 Diet and physical activity for weight loss

Different types of diets are proposed to promote weight loss, such as low-calorie, fat-restricted diets and low-carbohydrate diets [91]. Although findings from dietary intervention studies suggest that a low-carbohydrate dietary pattern may be most effective in inducing weight loss in the short term, there is no conclusive evidence that one diet is superior to another in the long term [91]. Independent of what kind of diet is suggested, the absolute energy intake should be adjusted based on body weight to obtain an energy deficit of 500–1000 kcal per day to give a minimum weight loss of 0.5–0.9 kg per week [92]. Very-low-calorie diets (VLCD) are defined as energy intake <800 kcal per day. These diets should only be used for relatively short periods e.g. 12–16 weeks, and they require medical supervision due to their very low energy value. The use of a VLCD leads to a better initial weight loss compared to other diets, but the results do not necessarily translate into better maintenance of the weight loss [93].

Performing less than 150 minutes of physical activity per week has minimal influence on body weight. Moderate-intensity physical activity of 150 to 250 minutes per week on the other hand is sufficient to prevent weight gain greater than 3% in most adults. It may also result in modest weight loss [81]. There is likely a dose effect of physical activity, with greater weight loss and enhanced prevention of weight regained if the individual performs 250 to 300 minutes per week of moderate-intensity physical activity [81]. High intensity physical activity provides greater weight loss than low intensity physical activity [94]. The effects of resistance training for prevention of weight gain are largely unknown owing to a lack of research in this area. Resistance training does not seem to be effective for weight loss but is associated with increases in fat-free mass and decreases in fat mass [81].

A combined diet and exercise program provides greater long-term weight loss compared to a diet-only programs [95] or an exercise-only programs [94]. Even if a diet in combination with exercise results in significant and clinically meaningful initial weight loss, [95, 96] it has historically been associated with partial weight regain and poor long-term weight loss [95].

1.4.2 Bariatric surgery for weight loss

Bariatric surgery, also known as weight loss surgery, is associated with greater long-term weight loss than conventional treatment, as well as a lower risk of disease and decreased overall mortality [97, 98]. The benefits of surgery should, however, be weighed against the risk of complications, for example bleeding, thrombosis/embolism, infections, pulmonary failure and even perioperative mortality [97, 99]. The overall mortality for the first 30-days after bariatric surgery is reported to be 0.28% internationally [100] and 0,046% in Sweden [101].

Bariatric surgery is usually only considered when a person has a BMI >40 kg/m^2 or >35 kg/m^2 with related conditions (co-morbidity), or when other treatments have failed [102, 103]. A number of different bariatric procedures are available, and most surgeries are currently performed by laparoscopic surgery. Results following laparotomy and laparoscopic surgery are similar, but the recovery time is shorter and wound complications fewer following laparoscopic surgery [99]. The most commonly performed procedures worldwide in 2011 were Roux-en-Y gastric bypass (46.6%), Sleeve gastrectomy (27.8%), Adjustable gastric banding (17.8%) and Biliopancreatic diversion with duodenal switch 2.2% [104]. Recent figures from Sweden indicate that approximately 8 600 bariatric surgery procedures (95% laparoscopic) were performed in 2011. Approximately 75% of these were performed on women. Moreover, 97% of the bariatric surgery procedures in Sweden were laparoscopic Roux-en-Y gastric bypass (LRYGB), while only 0.7% were laparoscopic Biliopancreatic diversion with duodenal switch (LDS) [101].

Laparoscopic Roux-en-Y gastric bypass (LRYGB)

LRYGB is performed by; 1. dividing the stomach horizontally and vertically with linear staplers to create a 25-ml gastric pouch. 2. an antecolic antegastric gastrojejunostomy is created between the pouch and the jejunum. 3. some 75-150 cm from the gastro-jejujunostomy on the alimentary limb a side-to-side jejunojejunostomy is created to the afferent loop about 50 cm distal to the ligament of Treitz. 4. the Roux-en-Y configuration is completed by dividing the jejunum between the anastomoses [105] (*Figure 1)*.

The previous view that gastric bypass surgery is a combination of mechanical restriction and calorie malabsorption is currently questioned [106]. Instead studies have shown that altered physiological regulation of appetite and food preferences as well as energy expenditure appears more important than simple mechanical restriction [106-110]. Since nothing is taken away during gastric bypass surgery it is technically possible to reverse it to original anatomy [99, 105].

Major complications associated with LRYGB include leaks at the junction of the stomach and small intestine, acute gastric dilatation of remnant stomach and bleeding. Other complications may be vomiting caused by narrowing of the stoma due to scar tissue development, incision hernias, intestinal obstruction and dumping syndrome [99]. Dumping syndrome is a well-known effect after bariatric surgery and comprises both gastrointestinal and vasomotor symptoms. Gastrointestinal symptoms include abdominal pain, diarrhea, nausea, and bloating. Vasomotor symptoms include fatigue, a desire to lie down after meals, facial flushing, palpitations, perspiration tachycardia, hypotension, and syncope [111]. A recent Swedish study reported no dumping symptoms, or only mild symptoms, one and two years after gastric bypass surgery in most patients, although around 12% of the patients perceived persistent symptoms, in particular, postprandial fatigue. Another 7% experienced problems with nausea and 6% had problems with fainting esteem [112].

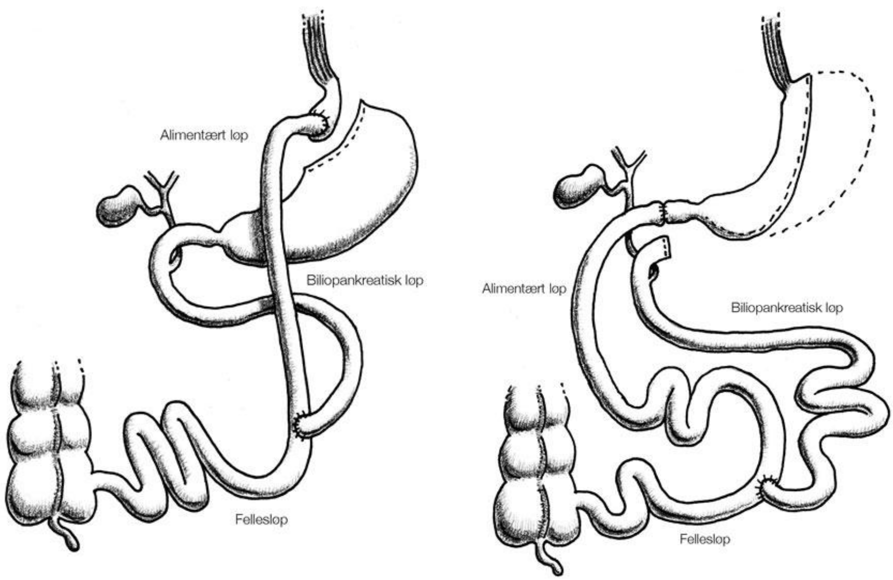

Figure 1. Drawings of a LRYGB (left) and a LDS (right) surgery procedure. Alimentaert løp; Alimentary limb, Biliopankreatisk løp; Biliopancreatic limb, FelleslØp; Common channel.

Originally published in: Aasheim ET et al. Kirurgisk behandling av sykelig fedme. Tidsskrift Nor Lægeforen 2007; 127:38-42. Reproduced with kind permission from the journal, first author and illustrator Ole-Jacob Berge.

Laparoscopic Biliopancreatic diversion with duodenal switch (LDS)

A LDS surgery includes: 1. resection of the stomach as a sleeve gastrectomy from the antrum to the angle of His along a nasogastric tube. 2. transecting of the duodenum 2-4 cm distal to the pylorus. 3. the small bowel is measured from the caecum and proximally for a common channel length of 100 cm. 4. an entero-entorostomy is created between the biliopancreatic and the alimentary limb. 5. measuring a 150-200 cm alimentary limb which is anastomosed to the duodenum [105] (*Figure 1)*.

The LDS is only a partially reversible procedure and the procedure is considered to be a technically demanding, especially when performed laparoscopically. The LDS is associated with an increased risk of perioperative morbidity and peri-operative mortality (2%) [99].

Side effects after LDS surgery include loose stools, stomach ulcers, offensive body odour and foul smelling stools and flatus. Other complications include anastomotic leak and anastomotic ulceration (3% to 10%), protein malnutrition (3% to 4%), hypoalbuminaemia, anaemia (less than 5%), oedema, asthenia (lack of energy) and alopecia (hair loss) [99].

1.5 Physical activity in connection with obesity and bariatric surgery

Individuals with obesity can achieve significant health improvements by performing the general recommendation [12] for physical activity. Significant positive effects include reduced CVD risk factors, such as lower diastolic blood pressure, triglycerides and fasting serum glucose and increased HDL levels. These effects are independent of weight loss in physically active adults with obesity [94]. Both high and low-intensity physical activity results in reduced systolic blood pressure and lowered serum triglycerides. However, high-intensity physical activity has a greater positive effect on fasting serum glucose than low intensity physical activity, suggesting that intensity affects the magnitude of the health benefit [94]. A twin study demonstrated that physically active individuals were leaner than sedentary ones. Moreover, physical activity reduced the influence of genetic factors that elevated the risk of high BMI and waist circumference. This suggests that the individuals at greatest genetic risk for obesity would benefit the most from physical activity

[113]. A study by Katzmarzyk et al [23] indicates that the highest mortality rates in obese individuals that spent most of their time sitting, and the authors therefore highlight the importance of limiting time spent sitting among individuals with obesity.

In a systematic review, physical activity correlated with greater postoperative weight loss following bariatric surgery in eleven out of thirteen studies [114]. Another systematic review also indicates that weight loss is greater in patients who exercise compared to those who did not exercise [115].

1.6 Physical fitness in connection with obesity and bariatric surgery

By suggesting that many individuals with obesity are not at increased risk for mortality, McAuly et al [116] have challenged conventional thinking about the dangers of obesity [116]. Instead, it is cardiorespiratory endurance that is highlighted as a powerful risk modifier [117]. Therefore, maintaining or improving the physical fitness of individuals with obesity, independently of weight loss, should be emphasized [116]. Low cardiorespiratory endurance is associated with premature mortality in individuals with normal weight, overweight or obesity, independently of other mortality predictors. The latter include smoking, hypertension and type II diabetes. In fact, physically fit obese men had a lower risk of mortality than physically unfit lean men [118].Supervised cardiovascular and muscle strength training for twelve weeks has been found to be both feasible and acceptable to patients with morbid obesity awaiting bariatric surgery. When combined with interdisciplinary lifestyle management, this training was found to effectively improve not only the patient's weight and physical fitness, but also health-related quality of life, and physical exercise beliefs [119].

It is known that patients with obesity have higher absolute muscle strength compared to lean subjects, even though they have lower relative muscle strength (in terms of total body weight) [120, 121]. It has also been shown that maximum strength decrease, in males, both for the lower and upper limbs, by 33.5% and 14.4% respectively, when massive weight loss was induced by bariatric surgery [122] . However, some studies have shown that resistance training not only preserved muscle strength but even increased it, despite a massive weight loss [85, 123, 124]. For example, a 12-week cardiovascular and muscular strength training program after bariatric surgery has been found to prevent a decrease in muscular strength in both biceps and triceps muscles, and even increase the muscular strength in quadriceps and hamstring muscles, even if FFM decreased [(124)]. The noticeable incongruity between the decline in FFM (22.4% of the total weight loss) and the maintenance of or increase in muscular strength is attributed to the accepted feature that during the early stages of a training program, neurological factors make the greatest contribution to the increase in muscle strength [(125)].

1.7 Experiences of physical activity among patients undergoing bariatric surgery

A deep understanding of the human body's natural functions, as well as attention to individual experiences and perceptions of the body and bodily movement, are essential for physiotherapeutic interventions [(1)]. Despite this fact, scientific knowledge about patients' experiences of physical activity, both before and after bariatric surgery, is limited. It is known that some patients with obesity rely on assistance to keep up with changes in their diet and increased physical activity after a weight-reduction intervention. Men appeared more capable of being physically active and more comfortable with being active alone, without a training partner, while the women tended to desire or need company to remain physically active. Weight loss sabotage from a partner was a perceived barrier to physical activity and dietary change among some patients [(126)]. It is also known that older people, especially those considering themselves overweight, feel anxious when wearing bathing clothes in the presence of others. They compared themselves with others and were more comfortable wearing bathing-suits in the presence of people of the same sex, of the same age or older than themselves, or with a similar figure [(127)]. In addition it is known that a lack of perceived benefits, poor confidence in one's ability to exercise, and fear of injuries may obstruct physical activity after bariatric surgery [(128)].

1.8 The physiotherapeutic perspective on physical activity and physical fitness in connection with bariatric surgery

The physiotherapeutic perspective on physical activity and physical fitness in connection with bariatric surgery has until recently been neglected in medical health guidelines. In “The First Physical Therapy Summit on Global Health: Implications and Recommendations for the 21st century” (3) it is stated that physiotherapists are uniquely positioned to lead the struggle against and lifestyle-related conditions such as obesity. Further, physiotherapy education and research should ensure that physiotherapists across WCPT regions can use their expertise to effect a global change in lifestyle-related conditions. Furthermore, physiotherapists should educate patients and their families on matters related to health and the positive effects of physical activity (3). Because physiotherapists are exercise experts they have a major role to play in the prevention and management of obesity (129). The physiotherapist’s knowledge in patient-adapted and adjusted exercise is of great value, as the WHO state that adjustments must be made for each individual based on their exercise capacity and specific health risks or limitations (12).

According to a recent review (130) engagement in physical activity that results in improved cardiorespiratory endurance contributes to reductions in health risk, independently of whether or not it affects body weight in patients who have undergone bariatric surgery. The authors thereby claim that the gradual increase in the patients’ physical activity level to an adequate dose needs to be incorporated into the clinical interventions for weight control (130).

1.9 Problem areas covered in this thesis

At the outset of this research work, the literature indicated that there was a lack of knowledge related to the following topics:

- There was a lack of knowledge about how patients, both before and one year after bariatric surgery, experience physical activity. A better understanding of this topic might give health care professionals a better understanding and therefore better tools for guiding these patients into becoming more physically active.

- Previous studies diverged concerning the accuracy of different brands of pedometers used by individuals with obesity. As a Silva pedometer, model 56013-3, as well as the accelerometer Silva Ex3 plus, model 56026, were commonly used in Sweden and not earlier tested for accuracy for patients with obesity, an evaluation was needed. An intentional choice was made to only include women in the testing procedure as it is more common for women to go through bariatric surgery. Another reason was that the difference in body composition between the sexes could affect the accuracy of the tested pedometer and accelerometer.

- There was a lack of information on whether or not a bariatric surgery-induced decrease in BMI affects muscle endurance and muscle strength in women. There was also a lack of knowledge about the level of physical activity and time spent sitting one year after bariatric surgery in Swedish patients. Bariatric surgery has earlier been found to improve the distance walked during a six-minute walk test (6MWT), but there was no information whether the results were valid in a Swedish population of women. An intentional choice was made to only include women as it is more common for women to go through bariatric surgery and muscular endurance and muscular strength is partly dependent on sex. Previous studies have indicated to what extent muscular strength was affected by weight loss in male patients with obesity, but no equivalent research has been carried out that identifies the strength-weight loss relationship in women.

2 AIM

The overall aim of this thesis was to study different aspects of physical activity and physical fitness among patients before and after bariatric surgery.

The aims of the studies were to:

I. Describe how Swedish patients with severe obesity, awaiting bariatric surgery, experience physical activity.

II. Describe how Swedish patients experience physical activity one year after bariatric surgery.

III. Assess the accuracy of a specific pedometer (Silva pedometer, model 56013-3) and accelerometer (Silva Ex3 plus, model 56026) in Swedish women with obesity. Another aim was to study the impact of BMI, waist and hip circumference and waist-hip ratio on different pedometer and accelerometer positions on the body.

IV. Investigate physical fitness, physical activity level and time spent sitting in Swedish women before and one year after bariatric surgery.

3 PATIENTS AND METHODS

This thesis is based on four studies using different methodology designs and addressing both quantitative and qualitative aspects of physical activity and physical fitness among patients undergoing bariatric surgery. In *Table 3* a research design overview is shown.

Table 3. Research design overview

Paper	**I**	**II**	**III**	**IV**
Study design	Explorative descriptive study	Explorative descriptive study	Descriptive cross-sectional design	Descriptive longitudinal study
Setting	Sahlgrenska University Hospital, Gothenburg, Sweden or participants home	Sahlgrenska University Hospital, Gothenburg, Sweden	Sahlgrenska University Hospital, Gothenburg, Sweden	Sahlgrenska University Hospital, Gothenburg, Sweden
Participants	18 patients (9 women)	24 patients (17 women)	40 patients (40 women)	37 patients (37 women)
Data collection	Semi-structured individual interviews	Semi-structured individual interviews	6MWT, Step count by pedometer, accelerometer and manually	6MWT, Grip strength, unilateral isotonic heel-lift, unilateral isotonic shoulder flexion, bilateral isometric shoulder abduction, International Physical Activity Questionnaire
Analysis	Phenomeno-graphic approach	Qualitative content analysis	Parametric and non-parametric statistical analysis	Parametric and non-parametric statistical analysis

The demographics of the patients in Paper I-IV are presented in *Table 4.*

Table 4. Demographics of the patients in Paper I- IV. Data are presented as Mean (SD) *and Median (min-max).*

	Paper I (n=18)	**Paper II (n=24)**	**Paper III (n=40)**	**Paper IV (n=37)**	
				Before LRYGB	One year after LRYGB
Age (year), Mean (SD)	48 (10)	35 (7)	42 (9)	41 (10)	42 (10)
Age (year), Median (min-max)	*47 (29-62)*	*36 (21-49)*	*41 (26-63)*	*39 (23-63)*	*40 (24-64)*
BMI (kg/m^2) Mean (SD)	47 (8)	37 (6)	42 (6)	42 (7)	30 (6)
BMI (kg/m^2) Median (min-max)	*47 (38-68)*	*37 (28-56)*	*40 (34-63)*	*40 (34-66)*	*30 (23-46)*

SD; standard deviation, min; minimum, max; maximum, BMI; Body Mass Index

3.1 Paper I

A strategic sample of eighteen patients, nine women and nine men with severe obesity (BMI > 35 kg/m^2), scheduled for LRYGB surgery at Sahlgrenska University Hospital in Sweden, were recruited. The inclusion criteria were patients scheduled for LRYGB surgery at Sahlgrenska University Hospital in Sweden, with severe obesity, aged between 18 and 65 years, Swedish-speaking, mentally lucid and orientated at the time of the study. The purpose of using strategic sampling was to gain a variation in demographical variables; age, sex, ethnicity, socioeconomic background, degree of obesity as well as co-morbidity were considered. Individual semi-structured interviews were conducted with all patients before their LRYGB surgery. Ten patients were interviewed in a separate room in the surgical department at the University Hospital and eight were interviewed in their homes. Two of the authors (MW and MFO) and two physiotherapy students carried out the interviews, none of whom had any relation to the patients. The definition of physical activity and physical exercise [(4)] was given and explained to each patient before the interview. The interviews were exploratory and were initiated with an open question: *How do you experience physical activity?* The interviews were formed around the patients' responses, as the responses also resulted in new questions [(131)]. An interview guide, with questions that needed answers at some point during the interview, included the following questions: *Are you able to perform any physical activity, and if so, what kind of physical activity? How do you feel during physical activity?*

Do you think that the surgery will affect your ability to perform physical activity? All the interviews were audiotaped and lasted between 15 and 45 minutes. A verbatim transcription was made by a secretary and the physiotherapy students, and was checked for accuracy by the first author (MW).

3.2 Paper II

Paper II was part of a prospective randomized clinical study, the "ASGARD study", comparing two bariatric surgery methods (LRYGB and LDS) in patients with a BMI >50 kg/m^2 at referral. The "ASGARD study" was conducted in two Scandinavian hospitals: Sahlgrenska University Hospital, Gothenburg, Sweden and Akers Hospital, Oslo, Norway, and had the main aim of comparing different effects of the two surgical methods. A total of 60 patients were included, 30 patients from each centre. Inclusion and exclusion criteria as well as the results from the "ASGARD study" have been described elsewhere (105, 132). For Paper II, the following inclusion criteria were adopted: patients included in the "ASGARD study" operated at Sahlgrenska University Hospital one year ago, Swedish-speaking, mentally lucid and orientated at the time of the study. Of the 30 patients that had bariatric surgery at Sahlgrenska University Hospital one year ago, twenty-four patients accepted to participate in Paper II. A flow chart of included patients is shown in *Figure 2*.

The interviews were conducted one year after bariatric surgery in a separate room at the hospital where the patients could speak freely without being disturbed. The first author (MW) and a specialized nurse responsible for collecting data for the "ASGARD trial" conducted the interviews. The definition of physical activity and physical exercise (4) was given and explained to each patient before the interview. The interview focused on four different domains: physical activity, quality of life, expectations of surgery, and excess skin. The initial question, concerning physical activity, was "*How do you experience physical activity?"* This question was followed by additional open questions. Each interview lasted 15-40 minutes, was tape-recorded and then transcribed verbatim by a secretary and was checked for accuracy by the first author (MW).

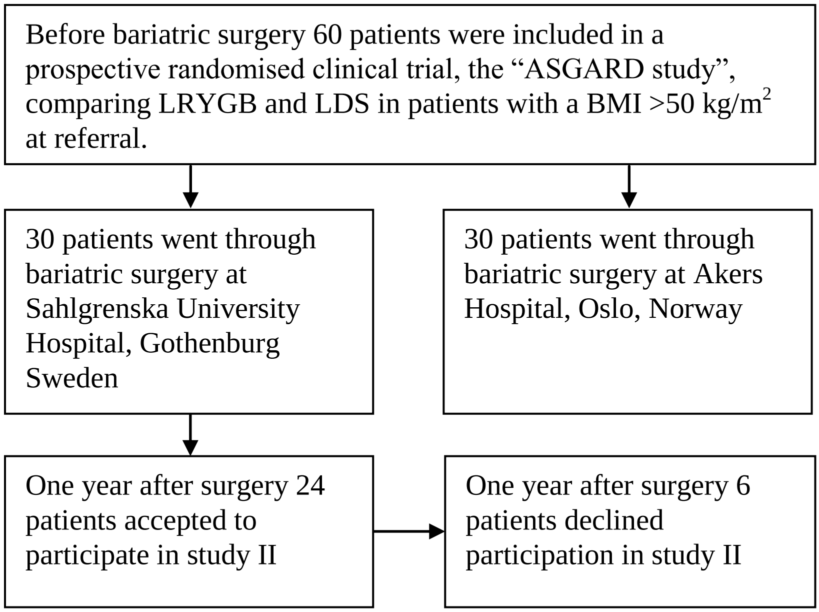

Figure 2. Flow chart of included patients in paper II

3.3 Paper III and IV

Paper III and IV were part of a large clinical study, studying excess skin and physical activity level in 200 men and women before as well as 12 and 18 months after LRYGB performed at the Sahlgrenska University Hospital in Gothenburg, Sweden during May 2009 to December 2011. The aim of the large clinical study was to investigate the development of excess skin after bariatric surgery and to detect potential predictors for the development of excess skin, its relation to physical activity and the functional limitations excess skin causes. The large clinical study had the following inclusion criteria: estimated LRYGB surgery within the next three months and able to understand spoken and written Swedish. The exclusion criteria were earlier surgery in the abdomen or a skin disease. The results from this study are not yet analyzed and not a focus of this thesis.

During Feb 2010 to December 2011, all 87 women scheduled to undergo LRYGB were also invited to participate in Study III and IV and an extra exclusion criteria were adopted: neurological, rheumatologic or orthopedic injury or illness that would hinder the assessments. The women received both written and verbal information about the studies and inclusion and exclusion criteria from a nurse during a preoperative preparation day at the department of surgery. Of the 87 women invited, 47 women wanted to participate in Paper III and IV and all fulfilled the inclusion criteria.

In Paper III the first 40 women were included and in Paper IV all 47 women were included. In Paper IV three women eventually did not go through surgery due to co-morbidity. Three women dropped out from the study and four were not available for follow-up, resulting in 37 women measured both preoperatively and one year postoperatively. The reasons for withdrawing from the study included personal reasons such as lack of time and traveling distance A flow chart of included women in Paper III and IV are seen in *Figure 3.*

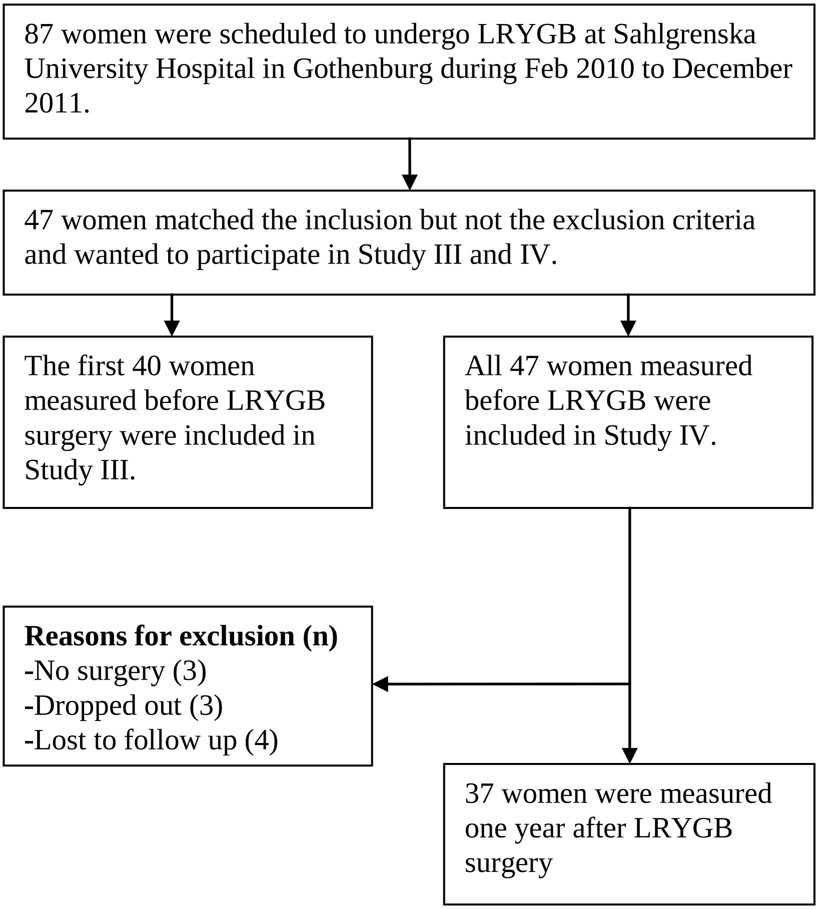

Figure 3. Flow chart of the included women in Paper III and IV.

3.3.1 Data collection methods

The women were measured one month before LRYGB surgery (Paper III and IV) and one year after LRYGB surgery (Paper IV) using the following data collection methods.

Demographic measurements

Height and weight were measured in light clothing and with no shoes, and body mass index (BMI) was calculated. Circumference measures of the waist and hip were performed according to WHO [(65)] using a measuring tape. The waist-hip ratio (WHR) was calculated by dividing the waist circumference by the hip circumference.

Physical activity

In Paper IV the short form of the International Physical Activity Questionnaire (IPAQ) [(133)] was administered for measuring physical activity and sitting time during the last seven days before each test occasion. IPAQ short comprises nine items that provide information on time spent walking, moderate- and vigorous intensity activity as well as time spent sitting. A total weekly physical activity level was calculated by taking the reported minutes per week in each activity category and multiplying it by a metabolic equivalent (MET) according to Guidelines [(134)], i.e. Walking = 3.3 METs, Moderate physical activity = 4.0 METs and Vigorous physical activity = 8.0 METs [(134)]. If data was missing for days the case was, in accordance with guidelines [(134)], removed from the analysis. If the number of days was completed but hours/minutes spent were missing, or “do not know” was selected, 10 minutes was expected, as this was the shortest amount of time considered.

Step count

In Paper III the women wore two pedometers and two accelerometers during two Six-Minute Walk Tests (6MWT) each. The 6MWT was performed according to the protocol of the American Thoracic Society in a 30 m pre-measured course [135]. The women performed two 6MWT and the time between the two tests was at least 1 hour, including a minimum of 20 minutes in sitting or until the heart rate returned to within 5% of its baseline value. During all the 6MWT, one of the authors (MFO), counted steps manually using a hand counter (CH-10, Voltcraft, Hirschau, Germany) to give a reference for step accuracy (actual steps counted).

The pedometers (Silva model 56013-3, Silva Sweden AB, Sollentuna, Sweden) were attached to the waistband of the women’s clothing. One pedometer was placed at the midline of the right hip (referred to as pedometer, right hip) and one in line with the spine at the lower part of the back (referred to as pedometer, back, in line with the spine). The accelerometers (Silva model Ex3 plus 56026, Silva Sweden AB, Sollentuna, Sweden) were placed around the neck (referred to as accelerometer, hung around the neck) as well as at the left hip (referred to as accelerometer, left hip), attached to the waistband of the women’s clothing.

The pedometers comprise a spring-suspended pendulum mechanism to detect vertical movement, which register every time the pendulum moved up or down. According to the manufacturer (Silva Sweden AB, Sollentuna, Sweden) the pendulum is calibrated for optimal function and includes software to filter out unwanted data, the pedometer therefore does not begin to register until at least six consecutive steps have been taken. According to the instructions, the pedometer should be placed vertically, i.e. not tilting, on the top of the trousers or on a belt close to the hip. Before the participant began the test, the test leader checked that the pedometers were positioned correctly- straight with no tilt.

The accelerometers contain a 3D sensor to detect movement by using 3 axes: X, Y and Z. Depending on how the individual moves, the accelerometer assesses movements using the 3 axes at the same time. It also contains software to interpret the movement, and its force. This software also filters unwanted data and for that reason, it takes 10 second before the accelerometer updates the steps taken. According to the instructions from the manufacturer (Silva Sweden AB, Sollentuna, Sweden) the accelerometer is able to count steps independently of how it is worn, as long as it is kept still and does not swing around during the walk. It may, for example, be hung around the neck.

Physical fitness

In Paper IV, the women were tested both before and one year after LRYGB surgery. On both occasions, the women's grip strength was measured with the "Grippit" instrument while muscle endurance was tested by muscular endurance tests and two 6MWT were carried out. To avoid carryover effects between the tests and tested extremities, the order of the tests was randomized in a random order table, using Microsoft Excel 2010, before the study started.

The 6MWT was performed according to the protocol of the American Thoracic Society in a 30 m pre-measured course [(135)]. The time between the two tests was at least 1 hour including a minimum of 20 minutes in sitting or until the heart rate returned to within 5% of its baseline value. Heart rate (HR) was assessed before and directly after the tests by using a fitness heart rate monitor (Fs2c, Polar, Kempele, Finland) carried around the thorax. The heart rate values from the women taking beta-blocker were excluded. At the end of each test perceived exertion was rated using the Borg Ratings of Perceived Exertion (RPE) scale [(136)]. Perceived dyspnea and pain were rated on the Borg Category scale with Ratio properties (CR-10 scale) [(137)]. The test-retest reliability for 6MWT has been found to be good (r_s= 0.95) for obese subjects, and could thus be used as a fitness indicator in clinical studies and clinical care in this population [(138)].

Grip strength was measured with the "Grippit" instrument (Detector AB, Gothenburg, Sweden), which is an electronic force transducer. The force transducer is based on strain gauges, and capable of sensing forces from 0 Newton up to 999 Newton with a resolution of 4 Newton (0.4%). It consists of a grip device, an electronic unit and an adapter for connection to a power supply. Standard arm and grip positioning is ensured with the use of the arm guide. The hand grasps completely around the handle, and the force exerted against the transducer in the handle is then recorded and displayed in the screen on the electronic unit, every 0.5 second while the 10 second long grip is in progress [(139)]. Both hands were assessed and the highest peak (maximum) value of three values was registered. [(140)]. The test–retest reliability of "Grippit" has been found to be good both for healthy women ($r_s \geq 0.88$), and women with rheumatoid arthritis ($r_s \geq 0.88$) [(139)].

The three muscular endurance tests [(141)] used in Paper IV are described in detail below.

- *Unilateral isotonic heel-lift*: The woman performed a maximal heel-lift on a 10° tilted wedge, one lift every other second, with pace held by a metronome (Taktell, Germany). The contra lateral foot was held slightly above the floor and, for balance, the wall was touched with the fingertips. The number of maximum heel lifts was counted for each leg.

- *Unilateral isotonic shoulder flexion:* The woman sat comfortably on a stool, with her back touching the wall, holding a dumbbell (2 kg). She was then asked to elevate her arm, from 0 to 90 degrees flexion, as many times as possible at the pace of 20 contractions per minute kept by a metronome (Taktell, Germany).

- *Bilateral isometric shoulder abduction:* The woman sat comfortably on a stool with her back touching the wall and with a 1kg dumbbell in each hand. She was then told to elevate both arms to 90° abduction and to keep this position as long as possible. The time, measured in seconds, that she was able to keep her shoulders in 90° abduction was recorded. The woman was given one warning if her arms descended from 90° abduction, before the test was stopped.

The test– retest reliability of these tests has been found to be good both for healthy individuals (r_s=0.79-0.98) and patients with chronic heart failure (r_s=0.90-0.99)[(141)].

3.4 Statistical analyses

For descriptive statistics, mean values and standard deviation (SD) were given for ratio and interval data. Mean and SD were also used when the median and mean values were close and a normal distribution could be assumed. Whereas median values and minimum-maximum (min-max) or inter-quartile range (IQR) were used for ordinal data and skew distributions. Median values were also used in the demographic data in Paper II, according to instructions from the journal. Parametric analysis methods were used for normally distributed intervals or ratio data, while non-parametric analysis methods were used for data with small samples, non- normal distribution and nominal or ordinal data. Correlation was in this thesis defined as: little, if any (r_s < 0.25), low (r_s = 0.26-0.49), moderate (r_s = 0.50-0.69), high (r_s = 0.70-0.89), and very high (r_s = 0.9-1.00) [142].

Statistical calculations were made by SPSS version 17.0-20.0 or SAS version 9.2. All tests were two-sided and considered statistically significant if $p < 0.05$. An overview of statistical methods used in this thesis is presented in *Table 5.*

Table 5. Overview of statistical methods used in this thesis.

Statistical methods	**Paper**			
	I	**II**	**III**	**IV**
Descriptive statistics				
Mean (SD) or (min-max)	x		x	x
Median (min-max) or (IQR)		x		x
Differences within and between groups				
Chi_2-test				x
Wilcoxon signed rank test			x	x
Paired sample t-test				x
Correlation				
Spearman correlation coefficient (r_s)			x	x
Graphic				
Modified Bland-Altman Plots			x	

SD; standard deviation, min; minimum, max; maximum, IQR; interquartile range

Before starting Study IV a power analysis was conducted. A statistically significant mean increase in 6MWD of ≥54 [138] was wanted between before and one year after LRYGB surgery. Assuming a standard deviation of 85 m and a power level of 80%, a two-sided test with an alpha level of 5% indicated that it was necessary to have a minimum of 24 patients. To be able to detect differences in some of the other tests and to compensate for dropouts we decided to include approximately 45 women.

3.5 Interview analysis

Explanations of words or terms used in this thesis, related to qualitative method and the interview analysis, are given in *Table 6*.

Table 6. Explanations of words or terms related to qualitative methods and interview analysis.

Category	A category answers the question "What?" and must be exhaustive and mutually exclusive, i.e. no data related to the purpose should be excluded due to lack of a suitable category. Furthermore, no data should fall between two categories or fit into more than one category [(143)].
Credibility	Credibility deals with the focus of the research and refers to confidence in how well data and processes of analysis address the intended focus [(144)].
Dependability	The degree to which data changes over time and alterations made in the researcher's decisions during the analysis process [(144)].
First order perspective	How things really are; "the true nature" of the world around us [(131)].
Inductive content analysis	Inductive content analysis is used in cases where there are no previous studies dealing with the phenomenon or when it is fragmented [(145)].
Latent content	The latent contest of a text is its underlying meaning [(144)].
Manifest content	The manifest content of a text is its visible, obvious components [(144)].
Meaning Unit	Words, sentences or paragraphs containing aspects related to each other through their content and context [(144)].
Second order perspective	How a phenomenon is understood, perceived and experienced [(131)].
Theme and sub-theme	A theme answers the question 'How?' A theme is a thread of underlying meaning that runs through condensed meaning units, codes or categories, on an interpretative level. A theme can be seen as an expression of the latent content of the text [(144)]. Since all data have multiple meanings [(143)] themes are not necessarily mutually exclusive. A condensed meaning unit, a code or a category can fit into more than one theme. A theme can be constructed by sub-themes or divided into sub-themes [(144)].
Transferability	The extent to which the findings can be transferred to other settings or groups [(146)].
Trustworthiness	In qualitative research the concepts credibility, dependability and transferability have been used to describe various aspects of trustworthiness [(146)].

3.5.1 Phenomenographic approach

Phenomenography was developed in the early 1970s at the University of Gothenburg, Sweden, by a group of researchers within the domain of human learning [131]. The aim of this approach is to define the different ways in which people experience, interpret, understand, perceive or conceptualize various phenomena and aspects of the world around us. According to Marton [131], there are a limited number of qualitative different ways in which different people experience a certain phenomenon. The way in which a phenomenon is understood, perceived and experienced is called the second order perspective. This is in contrast with the first order perspective, which focuses on investigating how things really are, i.e. "*the true nature*" of the world around us [131]. Even if Phenomenography first was developed within the domain of education it has been used in other areas and Sjöström and Dahlgren [147] state that phenomenographic research is useful for understanding how patients experience their disease, its origin, symptoms, treatment and their situation [147]. In Paper I the analysis was performed according to the seven steps described by Dahlgren and Fallsberg [148]:

1. *Familiarization:* in order to attain an overview, the interviews were read thoroughly and repeatedly.

2. *Condensation*: the respondent's statements about physical activity were extracted in order to provide a concentrated and representative version of the dialogue.

3. *Comparison*: the extracted quotes were contrasted with each other in order to reveal sources of variation or agreement.

4. *Grouping:* similar quotes were collected in groups for preliminary classification.

5. *Articulating:* an attempt to reach preliminary descriptions of the essence of the quotes within each group was made.

6. *Labeling:* the categories were given names that reflected their essence.

7. *Contrasting:* in order to attain the definitive description of the unique character of every category, the categories were compared with each other.

Steps 4 and 5 were repeated several times with continual discussion among the authors. The authors then carried on through steps 6 and 7 continuing discussions until agreement was reached. The various aspects dealt with by the categories of description were identified and named during this final comparison.

3.5.2 Qualitative content analysis

Content analysis was initially developed to deal with "*the objective, systematic and quantitative description of the manifest content of communication*" (149), but has over time expanded to include not only quantitative research but also qualitative research. The qualitative approach is often used in research for example in the fields of nursing and education (144). Content analysis does not require an underlying theory and can be used when existing theory or research literature on a phenomenon is limited (150).

In Paper II, the interviews were analyzed using an inductive qualitative content analysis as described by Graneheim and Lundman (144). The first step in the analysis process included reading the interviews through several times to obtain a sense of the whole. Then the text regarding the patients' experiences of physical exercise was extracted and brought together into one text, which constituted the unit of analysis. The next step was to divide the text into meaning units. The meaning units were then condensed, while preserving their core intent, and labeled with a code. During this process the whole context was considered, as the codes were put together and abstracted into themes and sub-themes. The first author (MW) carried out the first analytical and interpretation process. The underlying meaning of the condensed meaning units were analyzed and discussed in an open dialogue with the other authors. When agreement was reached this process led to identification and formulation of themes and sub-themes. While it was not possible to create mutually exclusive categories, no categories were created.

4 ETHICS

All studies in this thesis were approved by the Ethical Review Board in Gothenburg, Sweden. The approved protocols have the following numbers: 609-03 (Paper I), 688-02 (Paper II) and 723-08 (Paper III and IV). Information about the studies was given both verbally and in writing to all patients before an informed written consent was obtained. The patients were allowed to withdraw at any point without giving a reason.

5 RESULTS

The main findings from Paper I and II are presented in the first section, *"Experiences of physical activity"*, and the main findings from Paper III and IV are presented in the next three sections: "*Physical activity*", "*Step count*" and "*Physical fitness*".

5.1 Experiences of physical activity

The nine different categories and the four aspects from Paper I are displayed in *Table 7,* while *Table 8* shows the four themes and six sub-themes that emerged from the analysis of the interviews in Paper II. The results are exemplified with excerpts from the interviews.

Table 7. The aspects and categories from Paper I.

Aspect	**Category**
The obese body	The excess weight itself was considered an obstacle to be physically active
	Physical activity implies weight loss
The mind	Physical activity gives a feeling of well-being
	To appear in public is uncomfortable
Knowledge	Knowledge about benefits of physical activity but difficulty finding the right level of activity
The environment	Difficulties to adjust physical activity to the level of others.
	The expectations of others can be both an inspiration and an obstacle.
	Exercising together stimulates activity
	Misleading in order to hide low activity level

Table 8. The themes and sub-themes from Paper II.

Theme	**Sub-theme**
Hindrances of physical activity	Physical Hindrance
	Mental Hindrances
	Social Hindrances
Physical activity with a less obese body implies achievement	Physical Achievement
	Mental Achievement
	Social Achievement
Coming to an understanding of the benefits of physical activity	
Need of support	

Before the bariatric surgery, patients experienced that the excess weight itself was an obstacle to being physically active. One year after surgery it was the physical side effects of surgery, such as diarrhoea and excess skin, that prevented patients from being as physically active as they would like to be. Both before and one year after surgery patients experienced that it was uncomfortable to appear in public, for example in bathing suit. Before the intervention it was excess weight that caused uneasiness, while one year after it was excess skin.

"Not that I can't do it (go swimming), but I don't want to stand there and be stared at." Paper I

"I don't go to any swimming pool, as there is so much excess skin on my arms and stomach. I just can't cope with it." Paper II

In both studies (I and II), patients articulated their difficulties in finding an appropriate activity level and they also expressed their need of support to do so. The patients also stated the importance of receiving support and help from friends and family in initiating exercise and maintaining a good activity level. This was true both before and one year after bariatric surgery.

"My buddy and I helped each other; it was a lot easier then. When he called I couldn't say I didn't feel like it — the only thing to do was to get dressed and go with him." Paper I

"I think that I need to go and exercise with someone. We nag a little at one another and I feel I have a friend; we try and find at least one day a week when we can exercise together." Paper II

Before surgery (Paper I), patients experienced difficulties in adjusting physical activity to the level of others, as their fitness level was so low. In some cases, exercising alone was the only option.

"If I'm out walking with someone, for example my friends, they usually walk faster than I do. I try to keep up but I don't have the energy. Then maybe I take a walk by myself instead at my own pace." Paper I

In both studies (I and II) patients described difficulties in finding a suitable group training activity.

"The instructors either drove you to exhaustion, or it felt like you didn't do anything . . . either it was too fast or too slow. . . . There are very few that get it right . . ." Paper I

Before the surgery, patients expressed that they needed to lose weight first if the physical activity level was to increase (Paper I). Even one year after surgery, patients still experienced that they needed to lose more weight before they could become more physically active (Paper II). The patients in paper II also believed physical activity to be essential for achieving and maintaining further weight loss.

"I'm not counting on that I will lose weight as quickly as I have during this first year, but say that I lose a further 10 kg this year coming, I'll be really pleased. Roughly 1 kg a month, I believe that exercise is needed too, I have noticed that the weight doesn't disappear on its own anymore." Paper II

One year after surgery (Paper II), patients described that it had become easier to move around and that this was one great benefit of becoming less obese after the surgery. Physical symptoms were no longer as prominent, and patients experienced positive feelings during physical activity. In Paper I patients also experienced a feeling of well-being, but mainly after completing the activity.

In Paper II, patients experienced that improved physical ability resulted in an increased capacity to contribute to supporting their family financially and participating in family activities.

"Yes, my husband of course thinks that it's fantastic that we can work outdoors together, we have a farm, and it makes a difference, as I haven't been able to help at all." Paper II

5.2 Physical activity

Paper IV indicates that the women walked significantly more minutes/week and were significantly more physically active at vigorous and moderate intensity levels one year postoperatively compared to baseline. The IPAQ values, shown in *Table 9*, are based on the women who answered the current IPAQ question both pre- and postoperatively.

Table 9. Result of IPAQ pre- and one year postoperatively LRYGB from Paper IV. Data are presented as Median (IQR).

	Before LRYGB	**One year after LRYGB**	**p-value**
Vigorous Intensity (MET-minutes/week), n=29	0 (480)	480 (960)	0.033
Moderate Intensity (MET-minutes/week), n=28	40 (240)	480 (1440)	0.039
Walking (MET-minutes/week), n=25	396 (1196)	1155 (2326)	0.018
Total (MET-minutes/week), n=29	1231 (2001)	2428 (2979)	0.001
Sitting time (minutes/day), n=18	480 (337)	360 (315)	0.206

IQR; interquartile range, MET; Metabolic equivalent

A high percentage of the women reported, at IPAQ, beeing physically active at the recommended level of more than 150 minutes/week, equal to > 600 MET-min/week, both preoperativley (70%) and one year postoperatively (82%), the difference was not significant (p>0.05).

5.3 Step count

In Paper III, the Wilcoxon signed rank test indicated a systematic difference between the actual steps counted and the measurements made by the pedometer placed on the right hip (p<0.001), the pedometer placed back, in line with the spine (p<0.001), and measurements made by the accelerometer placed on the left hip (p=0.015). No systematic differences were identified between the actual steps counted and the measurements made by the accelerometer hung around the neck (p=0.103).

The intraclass correlation coefficient (ICC) between actual counted steps and the steps registered by the Silva pedometers was 0.13 for the one placed at the right hip and 0.20 for the one placed back in line with the spine. Corresponding figures for the accelerometer hung around the neck is 0.99, and for the left hip 0.41.

The results (Study III) further indicated that the pedometer undercounted with more than 50 steps in 45% of the tests when the pedometer was placed on the right hip, and in 24% when it was placed back in line with the spine. The corresponding figures for the accelerometer were 1% (hung around the neck) and 20% (left hip).

The correlations between the different locations of the tested pedometer and accelerometer and BMI, waist circumference, hip circumference and hip-to waist ratio were little (if any) to low.

5.4 Physical fitness

In Study IV, all women improved their 6MWD one year postoperatively, compared to baseline. The average increased 6MWD was 67 m the minimum being 6 m and the maximum 140 m. HR, perceived exertion and dyspnea were significantly lower, and the women experienced significantly less muscular and skeletal pain, particularly in the knees and feet, during the 6MWT one year postoperatively in comparison with baseline. *Table 10* shows the results from the 6MWT.

Heel-lift, shoulder flexion and shoulder abduction improved significantly one year postoperatively as compared to baseline but there was no statistical difference between grip strength pre- and one year postoperatively. *Table 10* presents the results of the included tests.

Table 10. Results of 6MWT, peak grip force, unilateral isotonic heel-lift, bilateral isotonic shoulder flexion and bilateral isometric shoulder abduction before and one year after LRYGB (n=37). Data are presented as Mean (SD) or ***Median (IQR)****.*

	Before LRYGB	**One year after LRYGB**	**p-value**
6MWD (m)	532 (81.0)	599 (70.5)	<0.001
Heart rate after 6MWT (beats/min), n = 36	144 (21)	128 (21)	<0.001
Perceived exertion after 6MWT (Borg RPE scale)	***14 (2)***	***13 (2)***	0.005
Perceived dyspnea after 6MWT (Borg CR10 scale)	***4 (2)***	***3 (1)***	0.001
Perceived pain after 6MWT (Borg CR10 scale)	***3 (3)***	***1 (2)***	<0.001
Peak grip force, Right (N)	298 (102)	287 (62)	0.307
Peak grip force, Left (N)	295 (92)	276 (60)	0.148
Unilateral isotonic heel-lift, Right (no.)	15 (9)	24 (7)	<0.001
Unilateral isotonic heel-lift, Left (no.)	15 (9)	23 (9)	<0.001
Unilateral isotonic shoulder flexion, Right (no.)	37 (27)	55 (55)	0.005
Unilateral isotonic shoulder flexion, Left (no.)	31 (23)	44 (51)	0.016
Bilateral isometric shoulder abduction (s)	45 (35)	115 (49)	<0.001

6MWT; six minute walk test, SD; standard deviation, IQR; interquartile range, m; meters, 6MWD; six minute walk distance, N; Newton, no.; number, s; seconds

6 DISCUSSION

The methods, main findings and conclusions in this thesis are discussed with respect to the aims and clinical implications. Different study designs were used in this thesis in order to assess the different aims of the included studies.

6.1 Experiences of physical activity

The results from this thesis indicate that prior to undergoing bariatric surgery (Paper I), patients experienced that the excess weight itself was an obstacle to being physically active. One year after surgery (Paper II), it was side effects of the surgery, such as diarrhoea and excess skin that prevented patients from being as physically active as they would like to be. Both before and one year after surgery patients felt uncomfortable to appear in public, for example in a bathing suit. Before surgery it was excess weight that caused this uneasiness, and one year after surgery it was excess skin. This shift in embarrassment factors was not seen in a study from the Netherlands (128), which instead observed a decrease in embarrassment after bariatric surgery. Another interesting result was that the patients were less fearful of injury and were more likely to believe in the benefits of exercising. They also felt more confident (128). These results are in good agreement with our observations from Paper II, in which the patients after surgery also gained an increased understanding of the benefits of physical activity.

According to the results from Paper I, before bariatric surgery, the patients experienced that the excess weight itself was an obstacle to being physically active. This is in good agreement with an Australian study (151), in which patients reported "being too fat" as a barrier to being physically active, linked to feeling too shy or embarrassed, or being lazy or not motivated. For women, one obstacle was self-image, as they did not perceive themselves as sporty (151).

In Study I patients experienced difficulties in adjusting to the physical activity level of others, as their fitness level was so low, and in finding a suitable group training activity. In some cases, exercising alone was the only option. In both studies (I and II) patients also expressed difficulties in finding an appropriate activity level, and a need of support and help to do so. To overcome this, some approaches have emerged in the literature. One is to place a greater emphasis on programs encouraging easily achievable, regular low- to moderate-intensity activity, as these may be useful in overcoming embarrassment about participation, which is likely to be emphasized in programs requiring more vigorous physical activity [(151)]. Another approach, suggested by The American College of Sports Medicine [(46)], emphasizes the importance of having appropriate and specific training goals. Training should be an individualized process using appropriate equipment, program design, and exercise techniques needed for the safe and effective implementation of a program to attain training with optimal resistance. Although this statement holds for all people, it is of even greater importance for people with obesity. Furthermore, it is recommended that trained and competent strength and conditioning specialists should assist with optimizing the safety and design of a training program [(46)].

The results from Paper I and II further imply that it is important for patients to receive information, both before and after bariatric surgery, about the health benefits that can be achieved by increasing the level of physical activity. The conclusions drawn from both studies thus suggest a need for both pre- and postoperative coaching by a physiotherapist, who is an expert in adapting physical activity when capacity is limited, for example as a consequence of injury, disease or environmental factors [(2)]. With proper preoperative information and coaching about the health benefits associated with improving the physical activity level, the patients may experience a stronger motivation to increase their level of physical activity, without losing weight first. Moreover, with corresponding postoperative coaching and individualized training programs, put together by a trained physiotherapist, there may be less need for further weight reduction before the patient feels that she can become even more physically active. Our results further indicate that it was regarded important to receive support and help from friends and family in order to initiate exercise and maintain a good physical activity level, both before (Paper I) and one year after bariatric surgery (Paper II). These results are in line with the recommendation from the British Association of Sport and Exercise Sciences [(152)] that beginners should find activities they enjoy and gain support in becoming more active from family and friends.

Gibson and Marin [(153)] have argued that qualitative research can be helpful for physiotherapists to understand the complexities of health and human behavior [(153)]. This argument serves as a basic point of departure in this study, and results from Paper I and II have produced an increased understanding of personal experiences of physical activity, before and one year after bariatric surgery. This knowledge may be helpful for physiotherapists when meeting these patients and in making physical activity feasible for them.

The phenomenographic approach was chosen for analyzing the interviews in Paper I. When a variety of unique perceptions of a phenomenon in a population is to be studied, phenomenography is a suitable research approach [(147)]. In Paper II, a qualitative content analysis was chosen, as the interviews did not provide a good basis for creating mutually exclusive categories. According to Graneheim and Lundman [(144)] it is not always possible to create mutually exclusive categories when a text deals with experiences, and, that it is possible to instead use themes.

Patton writes that “there is no right qualitative approach any more than there is a right fruit” [(154)] and Krippendorff [(143)] also suggests that methodology is not a value in itself. Instead, it provides a language for talking about the process of research, not about subject matter [(143)]. Selecting the most appropriate method for data collection and the amount of data are important in establishing credibility. However, the amount of data needed to answer a research question in a credible way varies depending on the complexity of the phenomena studied, and, the data quality [(144)]. In both Studies I and II we have tried to give a rich and elaborate presentation of the findings together with excerpts to enhance transferability. We have also attempted to give a clear description of culture and context and have accounted for the selection and characteristics of the participants. However, even if we as authors can give suggestions about transferability, it is always the reader’s decision whether or not the results and conclusions are transferable to another context.

In Paper I, patients that represent a spread of age, sex, ethnicity, socioeconomic background and degree of obesity, were selected. Co-morbidity was also considered. Choosing participants with varying experiences increases the possibility of shedding light on the research question from different aspects [(154)]. The results from Paper I were validated using dialogical intersubjectivity [(155)], which entails the interviews being read separately by two of the authors, and then compared for similarities and differences until agreement was reached. In Paper II, the authors analyzed and discussed the interviews in an open dialogue until agreement was reached.

6.2 Physical activity

There seems to be a graded, linear relation between the volume of physical activity and health status, such that the most physically active people are at the lowest risk. However, the greatest improvements in health status are seen when people who are least physically active become physically active [156]. Because lack of physical activity is a metabolic risk factor independent of body weight, the postsurgical increase in physical activity is a favorable health change, regardless of the weight lost [128]. The improvements in total activity level (Paper IV), measured by IPAQ, from in median 1231 MET-minutes/week before to 2428 MET-minutes/week one year after LRYGB, are most likely one important factor in reducing the risk of developing lifestyle associated diseases and premature death in this group of women. Even when we found a significantly improved level of physical activity one year after LRYGB, 18%, or 5 women, were still not sufficiently physically active i.e. more than 600 MET-minutes/week. These women need advice and help in order to increase their physical activity level. While it is generally suggested that it is preferable to encourage people to become more physically active rather than to become physically fit, sedentary people will likely achieve the latter if they do the former [157].

The sitting time of women in our study (Paper IV) was in median 480 minutes/day before LRYGB and 360 minutes/day one year after. These figures are comparable to healthy Swedish women who spent in median 414 min/day sitting [158]. This trend (although not significant) is positive as the risk for all-cause mortality, independent of sex, age, physical activity level and BMI decreases when less time per day is spent sitting [159]. It is of great importance to advice and encourage patients before and after bariatric surgery to limit their sitting time and to break up prolonged periods of sitting by standing and moving about.

IPAQ was primarily designed for population surveillance, and according to the guidelines [134] it should not be used as an outcome measure in small-scale intervention studies. Nevertheless, IPAQ has previously been used to measure physical activity level before and after bariatric surgery [160, 161]. Over-reporting is an inherent limitation of validity when using physical activity questionnaires [39], especially in obese subjects [162]. In Paper I one woman described how she stretched the truth to hide her actual activity level. This is one example of how patients are fooling both themselves and others by saying that they are more active than they actually are. Overestimation of physical activity level can minimize the true protective effect of physical activity. However, even studies based on these less reliable self-reported measures of physical activity have shown marked protective effects on mortality [14].

It is found that even if IPAQ has acceptable criterion validity for use in healthy Swedish adults, it significantly overestimated self-reported time spent in physical activity [158]. In a systematic review from 2011 [163] concerning the validity of IPAQ, it is shown that IPAQ overestimated physical activity as measured by objective criterion by an average of 84 percent and that the correlation between IPAQ and objective measures of physical activity in the large majority of studies was lower than the acceptable standard. These results were confirmed in a recent study from Chile [164] that found that using IPAQ for activity measures led to significant over-reporting of physical activity and under-reporting of sedentary behavior, compared to objective, accelerometer-derived measures [164]. On the other hand it has been found that IPAQ successfully estimates VO_{2max} as well as submaximum exercise tests in college-aged healthy volunteers [165]. Consequently, the evidence to support the use of the IPAQ as an indicator of relative or absolute physical activity is weak. With this in mind, the absolute values in Paper IV considering physical activity level and time spent sitting needs to be evaluated further by objective methods such as for example accelerometers. Nevertheless the use of the same instrument (IPAQ), both before and after an intervention, should provide the possibility to detect differences. The main reason to support the validity of this assumption is that the same individual probably over-reports to the same extent on both occasions.

6.3 Step count

The accelerometer (Silva model Ex3 plus 56026, Silva Sweden AB, Sollentuna, Sweden) was found to be more accurate than the Pedometer (Silva model Pedometer Plus 56013-3, Silva Sweden AB, Sollentuna, Sweden). This result implies that the accelerometer is better suited for use in studies and for health promotion strategies for obese women. Our results from Paper III also indicated that the accelerometer was more accurate when hung around the neck compared to the left hip location. This knowledge is important for increasing reliability when using this accelerometer for step count in research.

In addition, our results from Paper III further indicated a major undercounting problem with the pedometer and this is in line with a result from a British study, [38] in which a similar Silva pedometer (Silva model 56012) was found to undercount on average 67% of the time in healthy volunteers [38]. The authors discuss the fact that undercounting is a major issue for patients as they may have to take hundreds or even thousands of more steps in order to reach their goal [38]. It is thus not only of great importance to test the accuracy of the step-counting device intended for research purposes, it is also important for healthcare staff to be aware of this undercounting problem when recommending pedometer-based walking exercises to women with obesity.

A limitation of Paper III was that gold standard was registered manually, and the assistant who registers the steps could be disturbed or lose focus. To address this problem, two tests were carried out, whereby two assistants counted steps, and the results showed 100% agreement. Although this does not confirm that all manual tests were equally precise, it gives a general indication of high reliability. Another limitation was that we did not check if, and to what extent, the pedometers tilted during the tests. Even if the pedometer and accelerometer were placed with no tilt at the start of the test, a tilt might have occurred during the test. Pedometer tilt has previously been found to affect accuracy [35]. A special belt onto which the pedometer and accelerometer could be mounted might have been a workable solution. On the other hand, in real life conditions the equipment is often placed on the waistband of the trousers. A further limitation of Paper III is that it is not possible to draw any conclusions about how accurate the pedometer and the accelerometer are during normal and slow gait. The reason is that the patients walk at their maximum speed during a 6 MWT and this limits the ability to generalize. Other studies have shown that pedometer error significantly increased at slow speeds [166-169].

6.4 Physical fitness

Paper IV demonstrated that women one year after LRYGB significantly increased their mean 6MWD, from 532 m to 599 m, and that perceived exertion, pain and dyspnea during the test decreased significantly. The preoperative results from the 6MWD are similar to those measured in Belgian women with severe obesity (mean BMI 41 kg/m^2), who had a mean 6MWD of 538.9 m [170] and a group of Swedish women (mean BMI 39 kg/m^2) whose mean 6MWD was 531 m [171]. One year postoperatively the women in our study had a mean BMI of 30 kg/m^2 and a mean 6MWD of 599 m. This is comparable to another group of Belgian women [170] (mean BMI 32 kg/m^2), whose mean 6MWD was 591 m.

Even if the mean 6MWD increased from 532 m to 599 m in our group of women, the range of improved distance is wide (minimum: 6 m, maximum: 140 m). This means that some women did not enhance the 6MWD more than a few meters, despite a significant weight loss. For example, one woman only increased the 6MWD with 6 meters from 704 meters before to 710 meters one year after LRYGB. The reason for this result might be that that some women would have needed exercise training to enhance their cardiovascular endurance and walking ability during the postoperative period. Another explanation could be that the test was not sensitive enough, since some women walked near the maximum distance possible in 6 minutes already before the surgery. Some studies have published 6MWD reference values for healthy individuals [172, 173] . For example the mean 6MWD for women, 40-80 years, was found to be 555±81 m, in a multicenter study from seven countries [173]. In the same study the longest 6MWD was found to be 782 meters (one male subject) [173].

An individual improvement of the 6MWD of at least 80 meters in patients with obesity has been suggested to be of clinical importance i.e. the minimal important distance [174]. An improvement of > 70 meters has previously also been suggested to be the minimal important distance in patients with chronic obstructive pulmonary disease [175]. However, results from more recent trials indicate that the minimal important distance for 6MWD may be smaller than traditionally estimated, most likely owing to methodological and statistical differences. The minimal important distance for 6MWD is, therefore, now considered to be 25 meters in patients with chronic obstructive pulmonary disease [176] as well as in patients with coronary artery disease [177]. It is therefore clear that more research in this area is needed in patients with obesity going through bariatric surgery.

HR, perceived exertion and dyspnea were significantly lower and the women experienced significantly less muscular and skeletal pain, particularly in the knees and feet, during the 6MWT one year postoperatively in comparison with baseline (Paper IV). Our results suggest that the women perceived less effort during walking as they lost weight. This is in line with results from an American study [178], and is probably due to decreased walking energy expenditure. In another study, walking energy expenditure in people who were obese was reduced more than could be expected on the basis of the amount of weight lost [179]. Explanations to the disproportionate reduction in energy expenditure include factors such as decreased mechanical work in overcoming friction between the thighs and between the arms and the trunk, as well as less extraneous motion in swinging the arms and moving the thighs due to reduced girth (179).

The Six-Minute Walk Test has been found to be highly reproducible (138) and well tolerated (180) in people with obesity. It evaluates the total and integrated responses of all the systems involved during exercise, i.e. the pulmonary and cardiovascular systems, neuromuscular units, and muscle metabolism. However, it does not provide specific information on the function of each of the different organs and systems involved in exercise or the mechanism of exercise limitation, as is possible with maximal cardiopulmonary exercise testing. The 6MWT assesses the submaximal level of functional capacity, while most patients do not achieve maximal exercise capacity during the test, instead, they choose their own intensity of exercise and are allowed to stop and rest during the test. However, because most activities of daily living are performed at submaximal levels of exertion, the 6MWD may better reflect the functional exercise level for daily physical activities (135). It would be interesting to correlate the 6MWD with a maximal exercise capacity test in patients before and one year after LRYGB.

In our work, we found no correlation between the difference in BMI and the difference in 6MWD. This is in accordance with results from a US study, (178) that also failed to find any significant correlations between percentage changes in 6MWD distance and weight loss over time.

Both fat mass and fat-free mass (FFM) decrease after weight loss and for bariatric surgical interventions, FFM loss varies from 12.7% up to 52.7% of the weight loss (55). Although the women in Paper IV most certainly lost FFM, our study demonstrated that they improved in all muscular endurance tests and that grip strength was preserved. The handgrip strength was not statistically different from reference values for healthy women, either before or one year after LRYGB (139). This is in accordance with results from a Belgian study (120), which did not find differences in handgrip strength between women with obesity and women of normal weight. On the other hand another study (124) found a decrease in grip strength 4 months after bariatric surgery, even in a group of patients that had 12-weeks of cardiovascular and muscle strength training. The authors' explanation is that the patients did not train grip muscle strength, and it is known that exercises must be specific to the type of strength required (124). In our case, we did not have any information about whether the women trained grip strength during the first year after the surgery.

The muscular endurance tests used in Paper IV are easy to administrate and do not require expensive equipment. Although these muscular endurance tests are often used in the physiotherapy clinic where the study took place, no other research on women, either before or after bariatric surgery has been made using these tests. One could argue that in this study we have chosen measurements that are highly dependent on weight, for example heel-lifts. The important factor must, however, be that the patients, one year after surgery, improve their results in all muscular endurance tests and therefore can handle their body more easily. It would be of interest to study muscular endurance, using the same tests as in Paper IV, in lean women as well as men with different BMI.

6.5 Gender consideration

The majority of the patients included in the papers that forms the basis for this thesis were female. An intentional choice was made to include only women in Papers III and IV, as it is more common for women to go through bariatric surgery and muscular strength is partly dependent on sex. Body composition also differs between the sexes, which could affect the measurements in both Paper III and IV. Further studies are needed on men to test if the same results are obtained for both sexes.

6.6 Clinical implications

Current scientific knowledge and results of the present thesis suggest that an increased physical activity level both before and after bariatric surgery is very important and that some patients need information and advice to initiate and find a suitable physical activity level. Even if both the physical activity level and the physical fitness increased at group level one year after bariatric surgery, some individuals still need and want advice concerning how to increase their physical activity level.

Physiotherapists have a leading role in primary and secondary prevention, aiming to postpone or manage lifestyle-related conditions [3], and so they can assist the patients in fulfilling the recommendations of the World Health Organization (WHO) [12] concerning a sufficient physical activity level. As it is preferable to spread out moderate/vigorous intensity physical activity over

5 or more days per week, it is important to encourage the patients to integrate physical activity as part of their daily lifestyle [12]. The accelerometer (Silva, model Ex3 plus 56026) can be used to increase step counts as part of a more physically active lifestyle. The WHO also state that muscle-strengthening activities, such as resistance training involving major muscle groups, should be performed on two or more days per week [12]. Muscle-strengthening activites are especially important after bariatric surgery as it have been indicated to not only preserve muscle strength but even increased it despite a massive weight loss [85, 123, 124].

It is important to offer individual help to patients as well as to offer group activities, both before and one year after bariatric surgery. This would give the patients a possibility to exercise together with other individuals with obesity, as patients expressed how good it felt to exercise with others in the same situation: “Exercising in a pool is lots of fun and especially if it’s a fun group, then it’s a social activity at the same time . . . really great to have someone to exercise with.” (Paper I). It is also important to offer these patients an adapted exercise environment so that they do not need to think: “Will I fit into this? Can I use this apparatus without getting stuck in it?” (Paper I).

It is always important, however, to perform physical fitness testing before starting an exercise program, to be able to prescribe an individually based exercise program on a suitable level. A fitness testing, including the tests used in this thesis, performed by a physiotherapist is therefore warranted both before and after bariatric surgery to be able to give personalized advice and exercise programs. As a result, improved physical fitness can be accomplished and as a consequence of this the patients will reduce their risk of many common lifestyle diseases.

7 CONCLUSIONS

The following specific conclusions are drawn from the Studies (I-IV):

- Many obstacles influence the capacity and willingness of paients to be physically active, both before and one year after bariatric surgery. The perceived obstacles are often related to excess weight, excess skin or feeling uncomfortable when appearing in public.

- One year after surgery, patients experience both achievements and difficulties with regard to their physical activity level. An increased understanding of the positive benefits of physical activity, from a patient perspective, was observed.

- Both before and one year after bariatric surgery, support is of importance to initiate, find and maintain a suitable physical activity level.

- The accelerometer (Silva model Ex3 plus 56026, Silva Sweden AB, Sollentuna, Sweden) was found to provide accurate step count readings when hung around the neck. The accelerometer is therefore suitable for use in studies and for health promotion strategies for obese women.

- The pedometer (Silva model Pedometer Plus 56013-3, Silva Sweden AB, Sollentuna, Sweden) was found to be inaccurate and displayed a major problem with undercounting.

- The physical activity level, at group level, was found to be significantly increased one year after LRYGB, compared to before surgery.

- Physical fitness, measured with 6MWT and muscular endurance tests, was found to have increased and grip strength was preserved one year after LRYGB.

In summary, even if both physical activity and physical fitness increased at group level one year after LRYGB, some individuals still needed and wanted help in finding a suitable physical activity level and maintaining it. The accelerometer is appropriate for use both in studies and for health promotion strategies for obese women.

8 FUTURE PERSPECTIVES

Several ideas for further research have arisen during the work on this thesis.

- There is a lack of knowledge and a need for reproducing the tests performed in Paper III and IV in male patients, both before and one year after bariatric surgery.

- Some of the tests included in Paper III and IV do not have comparable reference values. The tests performed in Paper III and IV should therefore be reproduced with both female and male patients of normal weight in order to obtain comparable reference values for each test.

- It would be interesting to investigate if using individualized goals together with the accelerometer, tested in Paper III, could increase step count in patients with obesity. The studies should be made both before, in the immediate postoperative phase, and during the first year after bariatric surgery.

- There is a clinical need for developing and evaluating a variety of individual and group exercise programs aimed at enhancing physical fitness in patients going through bariatric surgery.

- It would be interesting to correlate the 6MWD with a maximal exercise capacity test in patients before and one year after LRYGB.

- Further qualitative studies on the topic of experiences of physical activity after bariatric surgery in a longterm perspective are needed to investigate if the perceived obstacles and achievements identified in Paper II related to physical activity are still valid.

- To further study the accuracy of IPAQ vs. objective measurements in patients undergoing bariatric surgery.

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