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Hylonome

Original Article

Physical function and properties of quadriceps femoris muscle after bariatric surgery and subsequent weight loss

T. Lyytinen[1,2], T. Liikavainio[3], M. Pääkkönen[4], H. Gylling[5,6], J.P. Arokoski[1,7]

[1]Department of Physical and Rehabilitation Medicine, Kuopio University Hospital, Kuopio, Finland; [2]Palokka Health Center, Jyväskylä, Finland; [3]Muonio Health Center, Muonio, Finland; [4]Department of Surgery, Kuopio University Hospital, Kuopio, Finland; [5]Department of Medicine, Division of Internal Medicine, University of Helsinki, Helsinki, Finland; [6]Department of Clinical Nutrition, Institute of Public Health and Clinical Nutrition, University of Eastern Finland, Kuopio, Finland; [7]Institute of Clinical Medicine, University of Eastern Finland, Kuopio, Finland

Abstract

Objectives: To investigate the effects of bariatric surgery-induced weight loss on physical function, the properties of quadriceps femoris muscle (QFM), and the subjective disabilities of the subjects with excessive weight. **Methods:** Thirteen female and three male subjects were studied before and 8.8 months after Roux-en-Y gastric bypass (RYGP) operation. The health-related quality of life (RAND-36) and the self-reported disease-specific joint symptoms (WOMAC) were estimated. The objective physical function was evaluated with sock, repeated sit-to-stand, 6-minute walk, stair ascending and descending and timed up & go tests and the properties of the QFM were measured with ultrasound. **Results:** The average weight loss was 27.3 kg. Objectively measured physical function improved after RYGP operation. Physical functioning, physical role functioning and general health domain scores of the RAND-36 were significantly improved. The stiffness and function scores were lower after RYGP operation in knee OA subjects. The subcutaneous fat thickness and the absolute muscle thickness of QFM decreased, but the ratio of muscle cross sectional area/total body weight did not change. The fat and connective tissue proportion in the QFM muscle were significantly increased. **Conclusions:** The RYPG-surgery-induced weight loss exerts a positive impact on physical function but a negative impact on a muscle structure.

Keywords: Physical Fitness, Obesity, Weight Loss, Muscle, Bariatric Surgery

Introduction

Obesity has a major influence on daily living physical activities, aerobic capacity and muscle strength[1-3]. Obese individuals experience greater impairments in physical function compared to normal weight individuals e.g. obese individuals walk with a slower walking speed[1,2], have poorer performance in the transition from sitting to standing positions[1,4]. The obese subjects have also been shown to have a reduced aerobic capacity[1,5] and poorer body balance[6] compared to normal weight subjects. It has also been demonstrated that older obese persons with poor muscle strength are at a particularly high risk for suffering an accelerated decline in their walking speed and for the development of new mobility disability[3]. There is also evidence that obese individuals experience more musculoskeletal pain than their non-obese counterparts[7].

Obesity among adults is associated with significant health risks, for example is a major risk for the incidence of knee OA; thus, the aggressive treatment of excessive weight is favourable[8]. The surgical option, such as a bariatric surgery is presently considered to be an efficacious and successful treatment since it achieves long term weight loss[9], an improvement in comorbidities[10] and better health-related quality of life (HRQOL)[11,12].

Subjective physical function after bariatric surgery has been evaluated using questionnaires such as the Medical Outcome Study 36-item Short Form Health Survey questionnaire (SF-36)[11,13,14], Western Ontario and McMaster Universities Osteoarthritis index (WOMAC)[15] and physical activity questionnaires[12]. Josbeno et al.[11]

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Corresponding author: Tarja Lyytinen, MD, Address: Department of Physical and Rehabilitation Medicine, Kuopio University Hospital P.O.B. 1777, FI-70211 Kuopio, Finland
E-mail: tarja.t.lyytinen@gmail.com

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Variables	Baseline	Follow-up	P[a]
Age (year)	45.1±9.5	—	—
Height (cm)	169.8±8.49	—	—
Weight (kg)	127.0±19.7	99.7±17.5	<0.001
BMI (kg/m²)	44.0±5.3	34.5±4.8	<0.001
Plasma total cholesterol (mmol/l)	4.7±1.4	4.4±0.9	NS
HDL cholesterol (mmol/l)	1.04±0.24	1.39±0.31	<0.001
Plasma total triglycerides (mmol/l)	1.78±1.40	1.12±0.48	<0.05
Plasma glucose (mmol/l)	6.5±1.8	5.7±1.0	<0.05
Work load history (0-6)[b]	2.3±1.4	2.6±1.8	NS
Leisure-time physical activity (1-3)[c]	1.81±0.66	2.06±0.57	<0.05
Number of comorbidities (0-4)	2.0±1.15	—	—
Pain medication (yes (%))			
Paracetamol	31.3%	50%	NS
NSAIDs[d]	43.8%	6.3%	<0.05
Weak opioids	37.5%	31.3%	NS
Knee and hip range of motion (deg)			
Knee flexion right leg	124.7±9.2	136.3±10.1	<0.001
Knee flexion left leg	126.6±8.9	135.9±10.0	<0.001
Knee extension right leg	-0.83±7.1	-0.94±7.6	NS
Knee extension left leg	-0.83±6.7	-0.31±7.6	NS
Internal hip rotation right leg	36.9±9.3	40.0±9.0	NS
Internal hip rotation left leg	35.9±7.6	39.4±5.1	<0.05
External hip rotation right leg	38.1±5.4	41.3±6.2	<0.05
External hip rotation left leg	38.1±5.1	45.3±6.9	<0.05
Thigh circumference (cm)	71.4±7.3	61.7±7.4	<0.001

Values are mean ± SD or % of subjects.
[a] Student's paired sample t-test or Wilcoxon non-parametric test.
[b] The scale from 0 (no work) to 6 (in physical terms the most demanding occupation)[26].
[c] The scale from 1 to 3; 1= rare activity, 2= occasional activity, 3= frequent activity.
[d] Non-steroidal anti-inflammatory drugs.

Table 1. Subject characteristics before (baseline) and after (follow-up) bariatric surgery (n=16, in laboratory test n=14-15).

claimed that the subjective physical function was improved after bariatric surgery. Richette et al.[15] reported that the scores on all WOMAC subscales were improved. In addition other studies have shown that self-reported physical function was much better after bariatric surgery[12].

However, rather few studies have examined the effects of bariatric surgery on objectively measured daily living physical activities[11,12] or evaluated aerobic capacity[14,16] and muscle strength[17,18]. Josbeno et al. showed that bariatric surgery, especially the gastric bypass surgery, could improve physical function[11]. They used The Short Physical Performance Battery, which consisted of repeated chair stands, balance and 8' walk (the walking 2.44 meters in time) tests, to evaluate physical function[11]. Miller et al. stated that in obese patients with the high risk of mobility impairments, mobility and capacity of daily activity was increased after bariatric surgery[12]. Other studies have also reported improved aerobic capacity after bariatric surgery based on the results of a six-minute walk test[14,16]. On the other hand, in their study Stegen et al. reported a considerable decrease after bariatric surgery in dynamic and static muscle strength, as measured from quadriceps femoris muscle or hand muscles[17]. In turn, Hue et al. concluded that this relatively great lower limb force loss in obese individuals after surgery was relatively well tolerated because the relation between force and body weight was even improved[18].

Based on a dual energy X-ray absorbtiometry (DEXA) analysis, many studies have shown that the massive and rapid weight loss after bariatric surgery causes not only a loss of the total body fat mass but also the lean body mass[19]. However, there are also investigations which have demonstrated mainly fat loss with a relative preservation of lean tissue[20,21]. Little is known about the effects of weight loss after bariatric surgery on fat mass and the muscle structure of the lower extremities. Pereira et al. recently demonstrated that the weight loss experienced after bariatric surgery decreased the thickness of quadriceps femoris muscle (QFM) mass and fat mass[22].

The aim of this study was to assess the changes in physical function and the properties of the QFM in excessively obese subjects after bariatric surgery and the subsequent weight loss. By combining the results of questionnaires, including WOMAC[23] and Finnish-validated SF-36-item Health Survey RAND-36[24], as well as those of objectively determined physical function tests it was possible to acquire a more complete perspective of the physical capacity of the subjects who had gone through bariatric surgery. The working hypothesis was that weight loss would improve the physical function, the quality of life and that the subcutaneous fat thickness and thickness of QFM would decline after bariatric surgery.

Materials and methods

Subjects

The participants were recruited from the Unit of Clinical Nutrition at Kuopio University Hospital, Kuopio, Finland. The recruitment period was from October 2008 to August 2010. The entry criteria consisted of the patient being evaluated for bariatric surgery in Kuopio University Hospital and a willingness to take part in the present study. A previous knee or hip arthroplasty was used as an exclusion criteria. Each participant provided written consent to participate in this study after receiving detailed information about the study design. The ethics committee of Kuopio University Hospital approved the study design.

Fifteen female and three male middle-aged obese adults between 30 and 63 years were recruited as volunteer subjects for this study at baseline. The baseline measurement for each subject was performed before the bariatric surgery. The follow-up measurements were performed on average 8.8 (SD 3.8) months after the Roux-en-Y gastric bypass operation (RYGP). Two subjects refused to participate in the follow-up measurements due to personal reasons not related to study. Sixteen (n=13 females, n=3 males) of the original subjects participated in the follow-up. The characteristics of the subjects are presented in Table 1. The mean body mass index (BMI) of the subjects was 44.0 kg/m² (range 36.4-53.6) before the operation.

The standard posterior-anterior weight bearing semiflexed radiographs and lateral radiographs of both knees as well as the weight-bearing radiographs of lower limbs and pelvis were taken. The radiographs were evaluated using Kellgren-Lawrence (KL)[25] grading, in which grade ≥2 was regarded as knee or hip OA. Five of these individuals had a mild OA (KL2) and one had a moderate OA (KL3), but none had hip OA.

Questionnaires

All participants filled in questionnaires about their comorbidities, work history, use of pain relief medication and leisure-time physical activity. Four other major disorder classes except obesity were listed: cardiovascular, respiratory, diabetes and some other diseases. A basic questionnaire was used to obtain information on the physical activity of occupations [scale from 0 (no work) to 6 (in physical terms the most demanding occupation)][26]. The use (no use, 1-2 times per week or 3-4 times per week or over 5 times per week) of prescribed pain relief medication [i.e. paracetamol, non-steroidal anti-inflammatory drugs (NSAIDs) or weak opioids] was determined during the previous month. The intensity of leisure-time physical activity (scale from 1 to 3; 1= rare activity, 2= occasional activity, 3= frequent activity) was determined.

The self-reported disease-specific joint symptoms were assessed using the Western Ontario and McMaster Universities (WOMAC) Osteoarthritis index, which has been validated for the assessment of outcomes involving knee and hip OA[23].

Self-reported generic HRQOL was determined by using the RAND-36 questionnaire containing exactly the same questions as the Medical Outcome Study 36-item Short Form Health Survey (SF-36)[27], but the scoring for the general health and bodily pain subscales differs slightly. The reliability and construct validity of the RAND-36, as a measurement of the health-related quality of life in the general population, have been established[24].

Anthropometric measurements, measurement of knee and hip joint range of motion (ROM) and biochemical measurements

Anthropometric data were collected using standard clinic scales for weight (kg) and height (cm). BMI was calculated by dividing body weight by the square of body height (kg/m²). The same investigator measured the ROM (degrees) of the knee (knee flexion and extension) and hip (internal and external hip rotations) with a standard goniometer[28,29]. The thigh circumference (cm) was measured midway between the lateral joint space and the trochanter major[30]. After an overnight fast for at least 10 h, plasma glucose level, total cholesterol, HDL cholesterol and total triglycerides were measured before and one year after the bariatric surgery and analyzed enzymatically using the automated analyzer systems at the Central Laboratory of Kuopio University Hospital (ISLAB).

Ultrasound measurements

The properties of the QFM were measured with ultrasound (SSD 1000; Aloka Co, 6-22-1, Mure, Mitaka-shi, Tokyo, 181-8622, Japan) from the rectus femoris (RF), vastus lateralis (VL) and vastus medialis (VM) compartments using a 5-cm wide probe of 5 MHz frequency[28]. The measurement point was midway between the lateral joint space and the trochanter major. The thickness (cm) of the subcutaneous fatty tissue and the thickness of the muscle tissue, including the RF, VL and VM muscles, were assessed by means of a longitudinal real-time scan. The ultrasound images were further analyzed with Image J version 1.46r for Windows software (available as freeware from http://rsbweb.nih.gov/ij/). The QFM cross sectional area (CSA (cm²)) beneath the probe and mean echogenicity of the three muscle compartments were determined. The ratio of QFM CSA/ total body weight was also determined. The ultrasound method and its reproducibility with in elderly women, athletes, untrained men and obese adolescents have been described in more detail elsewhere[30-32]. It was assumed that increased echo intensity (echogenicity i.e. higher mean grey shade value) of the muscle reflected increased tissue composition heterogeneity i.e. increased fat and connective tissue proportion[30,31]. The results of quantitative ultrasound have been shown to correlate with values obtained from computed tomography of muscle cross sectional area and also with muscle composition measurements in elderly trained and untrained women[33]. It has also been shown that ultrasound can be considered as the diagnostic method of choice when assessment of the fat and lean body mass before and after bariatric surgery[34].

Physical function tests

The subjects were familiarized with the test procedure and purpose prior to performance of the physical function tests. The subject was allowed to take adequate pauses between separate tests in order to avoid fatigue. The same investigator supervised the testing sessions, providing similar verbal encouragement to every subject to do his/her best. The physical functioning was measured using a test battery performed in a randomized order except for the 6-min walk which was assessed at the end of the session. The tests were as follows:

Sock Test. In the sock test[35] the subject was asked to simulate putting on a sock in a standardized manner for both sides. Scoring was from 0 to 3, where score of 0 meant that the test did not produce any difficulty and score of 3 designated an inability to reach as far as the malleoli.

Repeated sit-to-stand test. In the repeated sit-to-stand test[36], each subject was asked to fold the arms across his or her chest and to stand up from a sitting position and to sit down five times as quickly as possible. The result was calculated the two-run time average.

Stair ascending and descending tests. In the stair ascending and descending test subjects walk 12 stairs up and down as quickly as possible. Ascent and descent were performed separately three times and the mean velocity (m/s) of 3 trials was calculated as the result of the test[29].

Timed up & go test (TUG). In the TUG test participants were asked to stand up from the chair, which was a standard-height chair with arm rests, walk 3 meters, turn, walk back and sit down again as quickly as possible. The result reported for three run average in seconds (s)[37].

6-minute walk test. In the six-minute walk test, subjects walked a-20-m distance back and forth for 6 minutes. The participants were asked to "walk as quickly and safely as you can for 6 minutes". The result was the total distance traveled (meters) during 6 minutes[38].

Statistical analysis

All statistical analyses were performed with SPSS statistics 19.0 for Windows. The normality of each parameter distribution was determined by the Kolmogorov-Smirnov test. Student's paired sample *t*-test was performed for the parameters which were normally distributed according to the Kolmogorov-Smirnov test. The nonparametric Wilcoxon signed rank test and Mann-Whitney test were utilized when the presence of a normal distribution could not be assured. The results were considered significant if *P* less than 0.05 between baseline and follow-up measurements. The subjects were also further divided into knee OA group (n=6) and non-knee OA group (n=10) according to the classification in the Kellgren and Lawrence scale[25].

Results

Characteristics of the subjects

The clinical features of the subjects and the mean of individual measured parameters before and after bariatric surgery are presented in Table 1. The baseline weight of the subjects was 127.0 kg (SD 19.7 kg), and the follow-up weight 8.8 (SD 3.8) months after bariatric surgery was reduced by 27.3 kg ± 8.9 kg (range 6-41.55 kg) or 21.5% (p<0.001). In the follow-up measurements, the BMI was 21.6% (p<0.001) lower than it had been at the baseline measurement.

Total plasma triglyceride and glucose concentrations were significantly (p<0.05) lower in the follow-up measurement compared to the baseline (Table 1). HDL cholesterol concentration was significantly (p<0.001) higher after bariatric surgery, whereas total cholesterol was unchanged.

The use of paracetamol and weak opioids did not differ between baseline and follow up measurements but the subjects utilized significantly fewer NSAIDs (p<0.05) after bariatric surgery. In addition, the leisure-time physical activity was 13.8% higher (p<0.05) at the follow-up measurement.

The knee flexion ROM values in both legs were significantly (p<0.001) better after bariatric surgery. The internal hip rotation in the left leg and the external hip rotation in both legs were significantly (p<0.05) higher after the extensive weight loss. Knee extension ROM did not differ between measurements. Thigh circumference was significantly (p<0.001) smaller after bariatric surgery.

There were no significant differences in the clinical features between knee OA subjects and non-OA subjects (data not shown). The knee extension ROM values were significantly (p<0.05) lower in the knee OA group compared to the non-OA group in both baseline and follow-up measurements (data not shown). There were no significant differences between OA group and non-OA group in terms of work load history, leisure-time physical activity and number of comorbidities (data not shown).

WOMAC

The WOMAC pain scores did not differ significantly between baseline and follow-up measurements but the stiffness and function scores improved significantly (p<0.05) in the follow-up measurement in knee OA subjects (Figure 1).

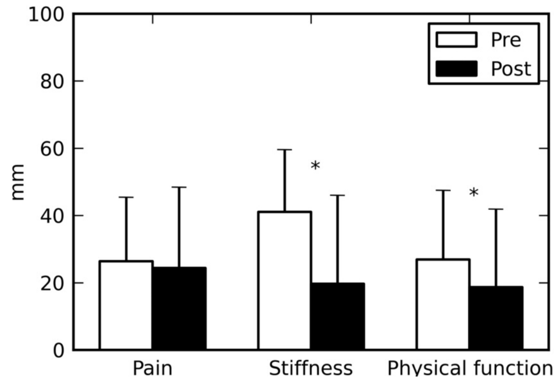

Figure 1. WOMAC scores (mean ± SD) in subjects with knee OA (n=6) before (pre) and after (post) bariatric surgery. *P<0.05 (Wilcoxon non-parametric test).

Variables	Baseline	Follow-up	P[a]
Physical functioning	58.5 ± 18.0	81.5 ± 25.6	<0.001
Role functioning/physical	39.4 ± 41.5	70.6 ± 40.7	<0.05
Role functioning/emotional	68.6 ± 43.3	80.4 ± 39.2	NS
Vitality	62.6 ± 20.0	70.6 ± 18.6	NS
Mental health	73.2 ± 17.4	77.4 ± 16.3	NS
Social functioning	74.4 ± 18.4	78.4 ± 15.5	NS
Bodily painlessness	63.7 ± 25.6	64.1 ± 29.4	NS
General health	57.1 ± 19.6	70.3 ± 17.4	<0.05

Values are mean ± SD.
[a] Wilcoxon non-parametric test.

Table 2. RAND-36 test results before (baseline) and after (follow-up) bariatric surgery (n=16).

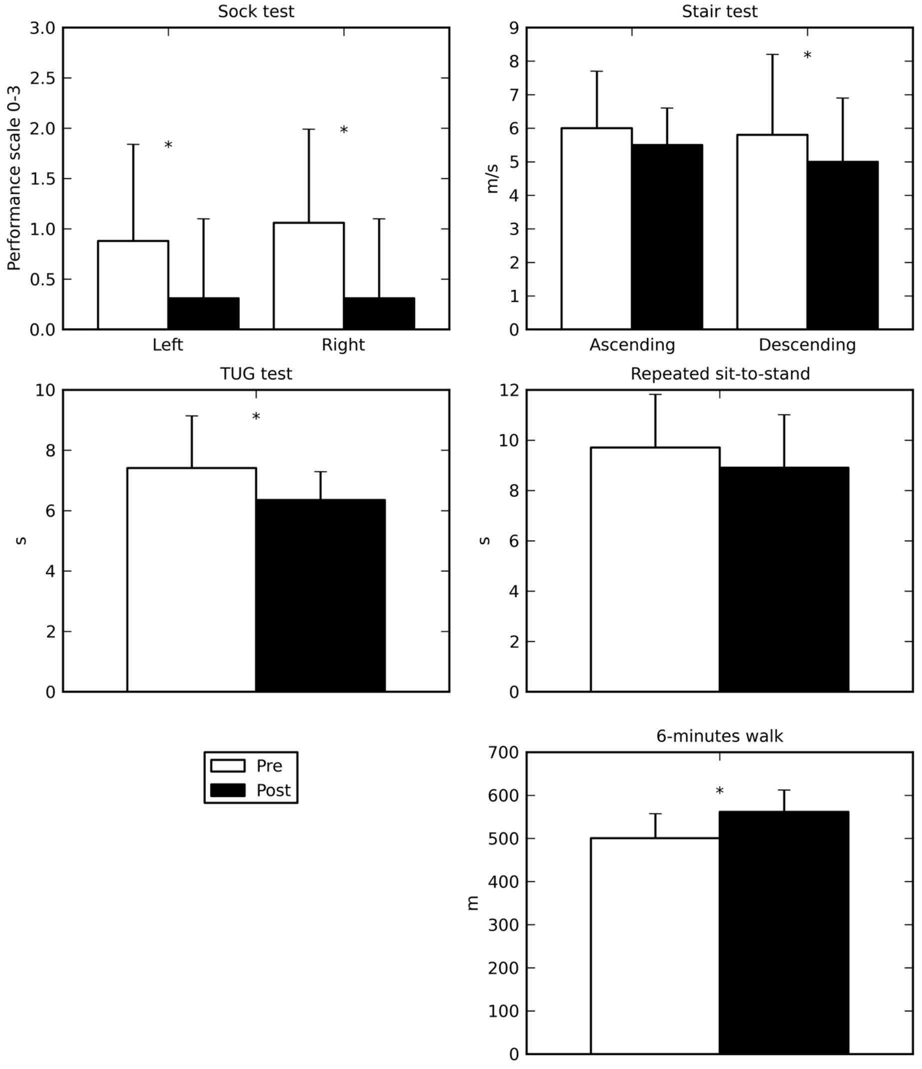

Figure 2. Physical function tests (mean ± SD) in subjects (n=16) before (pre) and after (post) bariatric surgery. *$P<0.05$ (Student's paired sample *t*-test, Wilcoxon non-parametric test).

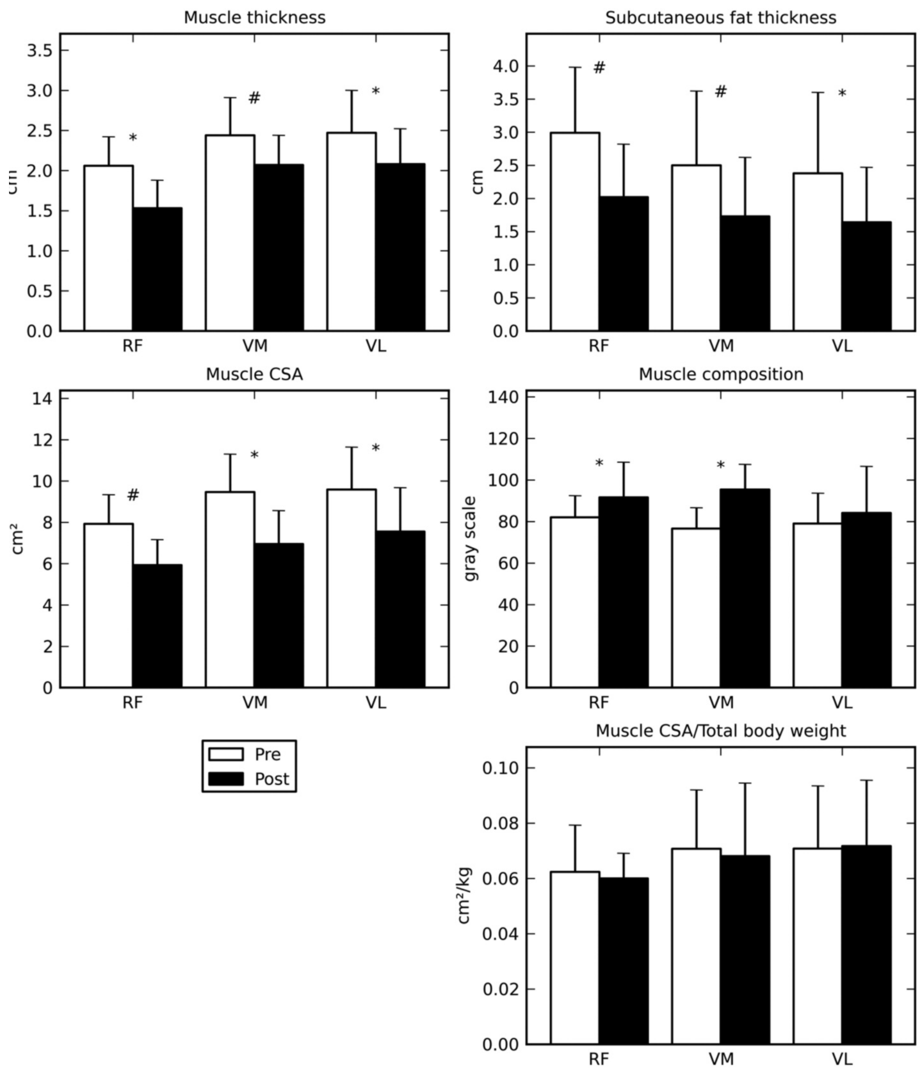

Figure 3. Structure of the quadriceps femoris muscle (QFM) (mean ± SD) in subjects (n=16) before (pre) and after (post) bariatric surgery. The muscles are RF = rectus femoris, VL = vastus lateralis, VM = vastus medialis. The figure illustrates the QFM thickness (cm), subcutaneous fat thickness (cm), muscle cross sectional area (CSA) (cm^2), muscle composition (gray scale) and the ratio of the CSA/total body weight (cm^2/kg). *P<0.05, #P<0.001, (Student's paired sample t-test).

RAND-36

Table 2 illustrates the results of each of the eight domains of the RAND-36 before and after weight loss. There was a statistically significant improvement in the physical functioning (p<0,001), physical role functioning (p<0.05) and general health (p<0.05) domain scores between the pre- and post-operative situation. In comparison with the knee OA group, the non-OA group showed no significant differences in RAND-36 domain scores after bariatric surgery (data not shown).

Physical function tests

The results of the physical function tests of the baseline and follow-up measurements are shown in Figure 2. Almost all results of the physical function, except for the stair ascending test and repeated sit-to-stand test, improved in the follow-up measurement. TUG test result was 14.3% (p<0.05) better in the follow-up measurement compared to baseline measurement. The results of the sock test with both right and left legs, the stair descending test result and 6-minute walk test result were also 70.8% (p<0.05), 64.8% (p<0.05), 13.8% (p<0.05), 12.1% (p<0.05) better in the follow-up measurement, respectively.

When comparing the knee OA group and the non-OA group, there was only one statistically significant test result, the results of the stair descending test were significantly (p<0.05) better in the non-OA group compared to OA group at the baseline measurement (data not shown). At the baseline measurement, there were no significant differences in the results of the physical function tests between these groups. At the follow-up measurements, the non-OA group was significantly better ($p<0.05$) in the repeated sit-to-stand test, but not in any other tests (data not shown).

Muscle composition

The absolute muscle thickness (cm) and the CSA (cm^2) in all thigh muscles (RF, VL and VM) were 25.7% and 25.2%, 15.8% and 21.3%, 15.2% and 26.6%, smaller in the follow-up measurement compared the baseline measurement, respectively (Figure 3). The ratio of CSA/total body weight in the separate part of QFM did not differ significantly when comparing the baseline and follow-up values (Figure 3). The thickness of subcutaneous fat was also significantly thinner at all measurement sites after bariatric surgery (Figure 3). The RF and VM, but not VL muscle compartments of the QFM, exhibited significantly ($p<0.05$) more heterogeneity after bariatric surgery (Figure 3). The QFM composition and size did not differ between knee OA group and non-OA group except that the absolute muscle thickness of VL was significantly ($p<0.05$) thinner in knee OA group after bariatric surgery (data not shown).

Discussion

After bariatric surgery, the measured objective physical function had improved when compared to the baseline measurements, which was as hypothesized. Furthermore, the RAND-36 survey indicated that the physical functioning, physical role functioning and general health domain scores of the HRQOL were all significantly improved in the follow-up measurement. In all muscles of the QF, the muscle and subcutaneous fat thickness and the muscle CSA decreased significantly but the ratio of CSA/ total body weight in the separate part of QFM did not differ and the proportion of fat and connective tissue of the QFM increased after bariatric surgery. In the biochemical measurements, plasma lipid and glucose profiles improved after bariatric surgery.

Various forms of the SF-36 have been used in previous reports of the bariatric surgery to evaluate the HRQOL, for example in our study we utilized RAND-36[11,13,39]. Generally speaking, many studies have demonstrated compatible improvement in the SF-36 domain scores with weight loss after surgery[11,13,39]. Our findings are not exactly similar to those in previous studies. In our study, the health status was significantly improved in only three of the eight areas assessed by RAND-36. We cannot find any single explanation for this inconsistency. This difference could be explained by other comorbidities, lifestyle factors such as current or former smoking, unhealthy diet, and alcohol use, all of which may have confounded the results. One must also remember that obesity is a chronic disabling disease, which impairs the overall health status and even after bariatric surgery, the subjects in our study were still obese.

The physical functioning was measured using a battery of validated tests that could be practically applied in general practice. Performance of the tests demanded strength in the lower extremities, joint mobility and balance and were intended to reflect normative daily activities. In our study, the objectively determined physical function tests tended to improve after bariatric surgery. However, the improvements were rather small and because the percentage difference in objective physical function tests results between baseline and follow-up measurements were not spectacular, one could speculate on the clinical importance of these findings. For example, in the repeated sit-to stand test and the stair ascending test, the results did not significantly improve after bariatric surgery.

It is also possible that some of the objective physical function tests do not properly measure the maximal physical performance of our study subjects. For example the repeated sit-to-stand test and the TUG test might be too easy for our subjects, those mean age was 45.1 years. The repeated sit-to-stand test and the TUG test are mainly widely employed in the examination of elders[40-42]. Unfortunately, definitive normative reference values for younger age-groups and obese subjects are lacking. It is possible that the differences would have been more marked, if these types of tasks had been prolonged to several minutes or the assessment of maximal muscle strength of the QFM instead of performance tests would have been used. However, based on the reference values for 6-minute walk test for healthy subjects[43], clear difference was found between the walking distance of the healthy subjects of the same age (age group 40-49 years) compared to our study subjects (in the healthy subjects mean 611(85 SD) m and at the baseline in our study subjects mean 501(57 SD) m). The mean walking distance (561 (51 SD) m) also remained worse off than the healthy population after bariatric surgery.

On the other hand, the objective physical function tests results are rather similar to those reported in other studies[11,12]. Josbeno et al. showed that bariatric surgery, especially gastric bypass surgery, did improve objectively measured physical function[11]. Miller et al also showed that in morbidly obese patients with a high risk of suffering mobility impairments, surgical methods to reduce body weight are able to increase mobility and improve objectively measured capacity of daily activities[12]. In some other studies, researchers have demonstrated that the weight loss achieved after bariatric surgery increased aerobic capacity as measured in the 6-minute walk test[14,16].

It is important to understand the associated changes in muscle structure, because the maintenance or strengthening of muscle mass is associated with augmented muscular strength and better endurance[44]. It could be postulated that, whereas light and intensive weight loss improve physical function, greater weight loss may lead to a more extensive loss of lean body mass, thus diminishing the benefit of intensive weight loss. Hue et al. demonstrated that the weight loss after bariatric surgery decreased the lower limb muscle force by about 33.5%, but when they proportioned the muscle force to the total body weight, they found an increased relative force after surgery[18]. In our study, the ratio of CSA/total body weight of the QFM did not change after bariatric surgery. This was not a surprising result as the muscle size of the QF is generally adapted to the total body mass. As the total body mass decreased dramatically and no extensive additional exercise training was performed, although a slight increase in overall physical activity was described by the patients, consecutively, the absolute CSA of the QFM decreased as well.

A justifiable fear about weight loss especially among the elderly people is the accompanying loss of fat-free mass with possible disastrous effects such as diminished functional capacity and altered metabolic function of the muscle tissue[45]. Our study revealed that major weight loss after bariatric surgery reduced both body fat mass and fat-free mass. Our findings are in accordance with those of Pereira et al., who demonstrated also a reduction in the thickness of the QFM and the subcutaneous fat after bariatric surgery[22]. However, they did not measure the composition of the QFM[22]. In our study, the muscle fat and connective tissue proportion increased after the bariatric surgery. This finding in connection to the decreased muscle thickness might partly explain the fact that no major changes were detected in objectively measured physical function tests.

There are also investigations of body composition changes after bariatric surgery; these have demonstrated mainly fat loss with a relative preservation of lean mass[20,21]. In these studies, restrictive surgical techniques that contribute to slower and lesser degrees of total body weight loss were used[20,21]. On the other hand, it has been shown that physical activity plus a weight loss intervention program decreased fat mass much more than muscle mass[46]. It has also been demonstrated by Chomentowski et al. that this accelerated muscle loss can be lessened with moderate aerobic exercise[45]. In our study, the subjects' leisure-time physical activity was significantly higher in the follow-up measurement, although this change was not so extensive. Obviously the minor increase in leisure-time physical activity could not compensate for the decrease of QF muscle thickness and CSA and no special exercise program was provided in our study. This might also partly explain the change of muscle size and muscle fat and connective tissue proportion. Based on above mentioned studies[45,46], it is possible that some kind of physical activity might prevent the loss of lean body mass during the weight loss intervention. Stegen et al. demonstrated that although the weight loss after bariatric surgery reduced dynamic and static muscle strength, they also reported that combined exercise training could prevent the decrease and even result in an increase in strength of most muscle groups[17]. Other studies in normal weight subjects have reported that long-term muscle training can maintain the muscle architecture and replace fat tissue with muscle tissue, in other words reducing the proportion of fat in the muscle tissue[30,31].

Skeletal muscle is the major site for disposal of ingested glucose in lean healthy normal glucose tolerance individuals[47]. In insulin resistance states, such as obesity, insulin-stimulated glucose disposal in skeletal muscle is markedly impaired[48]. Leichman et al. reported that the weight loss induced by surgery is accompanied by a reversal of insulin resistance and dramatic changes in skeletal muscle metabolism[49]. We observed significant improvement in plasma glucose profile after RYGP operation. This change in glucose level in weight-reduced patients might reverse the insulin resistance and lead to improved skeletal muscle metabolism.

We also compared the results between the knee OA subjects and their non-knee OA counterparts before and after bariatric surgery. In the objectively measured physical function test, only the stair descending test at baseline measurement and the repeated sit-to-stand test at follow-up measurement were significantly better in the non-OA group as compared to the knee OA group. The scores for stiffness and function but not the scores of pain on WOMAC subscales improved after bariatric surgery[15]. Richette et al. demonstrated significantly improved scores on all WOMAC subscales after bariatric surgery in knee OA subjects. The differences can be explained partly by the fact that we had only six knee OA patients, and these suffered mainly from mild radiographic disease with minor knee pain.

We recognize some limitations in the study. We are aware that its sample size was small and our subject population included only a few men and pre- and postmenopausal women in different age categories. The results of this study may not be generalizable to all obese populations, because most of the subjects were women. On the other hand, our study design was versatile and we measured physical function objectively using several tests and also subjectively from the patients' point of view.

The assessment of properties of QFM was also challenging among obese individuals mostly because of the technical limitations due to the thigh size and thick layers of soft tissue over the trochanter major. Unfortunately we did not perform pretesting to ensure comparable reproducibility in our study subjects. The most commonly used methods to evaluate the body composition are DEXA and computed tomography, which are sensitive and specific methods, but expose the patient to ionizing radiation. However, the good reproducibility and very good accuracy of ultrasound method compared to reference DEXA measurements have been described in obese adolescents by Pineau and co-workers[32]. It has also been shown that ultrasound can be considered as the diagnostic method (i.e. to determine the thickness of subcutaneous adipose tissue and muscle of the lower limbs) of choice when assessment of the fat and lean body mass is required in morbidly obese patients before and after bariatric surgery[34]. It could be also possible that the thickness of subcutaneous adipose tissue might affect muscle echogenicity. However we tried to minimize the effect of subcutaneous fat on muscle echogenicity by using exactly the same settings of ultrasound before and after bariatric surgery and by positioning the focus to the domain of the muscle in our study.

Conclusions

It was observed that surgical treatment of clinically excessive obesity is beneficial and has a positive impact on physical function, the subcutaneous fat thickness of the QFM and subjects' perception of their health status. However, major weight loss does exert a negative effect on the QFM muscle thickness and the CSA and the fat and connective tissue proportion of the QFM. However, the ratio of QFM CSA/ total body weight did not change. We think that longitudinal studies are warranted to demonstrate whether there is any benefit from continued and maintained weight loss. Further prospective studies are also needed to examine the effect of physical activity interventions designed after bariatric surgery to reduce fat and increase muscle mass. Nonetheless, our study results do need to be confirmed with a larger study population and the results can only be viewed as preliminary.

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