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CICLO XXXII

Functional capacity in patients with obesity before and after sleeve gastrectomy: implications for exercise prescription

Coordinatore: Ch.mo Prof. Paolo Angeli

Supervisore: Ch.mo Prof. Andrea Ermolao

Dottoranda: Valentina Bullo

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ABSTRACT

Background

Obesity is a chronic multifactorial pathology caused by environmental, behavioral and genetics factors, with negative impact on general health, quality of life, and increased risk to fall into disability and morbidity. Non-surgical management of obesity consisted on a multicomponent approach, including behavioral therapy, pharmacotherapies, and lifestyle change to reduce the energy intake with diet, and increase physical activity. Because few patients achieved an important weight loss with lifestyle change, many undergo to bariatric surgery.

Materials and methods

This study is divided into two phases. In the first phase, the aim is to evaluate functional capacity of patients with obesity before and after sleeve gastrectomy to analyzed changes of maximal oxygen consumption, muscular strength, static balance, level of physical activity and quality of life. In the second phase, the aim is to analyze the effect of 1 month supervised physical exercise protocol performed 6 months after surgery. One hundred and seventy-nine patients with obesity were recruited and valuated 1 month before and 6 months after sleeve gastrectomy. Physical functioning evaluation consisted on: cardiopulmonary capacity, muscle strength, static balance, level of physical activity, and quality of life. After surgery, 28 patients were recruited for a 10-sessions of supervised physical exercise protocol.

Results

As expected, after surgery were recorded significant reduction of body weight, body mass index and waist circumference. Absolute muscular strength of upper and lower limb decreased, while strength adjusted by body weight increased significantly. Static balance improved in females, while males tend to worsen their balance control. Also quality of life and level of physical activity increased after surgery. After physical exercise protocol, patients improved muscular strength, dynamic balance, and flexibility capacities.

Conclusion

After sleeve gastrectomy, patients with obesity improved their functional capacity, increased the time dedicated to physical activity, and improved quality of life. Even if the weight loss was detected mainly by surgery, physical activity is strongly recommended to avoid muscle mass reduction and to improve quality of life.

RIASSUNTO

Introduzione

L'obesità è una patologia cronica con eziologia multifattoriale, comprendenti fattori ambientali, comportamentali e genetici. L'obesità ha un impatto negativo sulla salute generale del paziente, sulla qualità della vita, e inoltre aumenta il rischio di sviluppare patologie croniche. Il trattamento non chirurgico dell'obesità consiste in un intervento multidisciplinare comprendente terapie comportamentali e farmacologiche, così come il cambiamento dello stile di vita riducendo l'introito calorico attraverso una dieta, ed aumentando il dispendio energetico con l'esercizio fisico. Siccome pochi pazienti raggiungono risultanti soddisfacenti con questo approccio, molti si sottopongono a chirurgia bariatrica.

Materiali e metodi

Lo studio si divide in due fasi. Nella prima fase, lo scopo è di valutare l'efficienza fisica in pazienti con obesità che si sottoporranno ad operazione di gastrectomia verticale, con l'obiettivo di analizzare i cambiamenti nel massimo consumo di ossigeno, forza muscolare, equilibrio statico, livello di attività fisica e qualità della vita. Nella seconda fase, lo scopo è di valutare gli effetti di un protocollo di esercizio fisico supervisionato della durata di un mese, nei pazienti che si sono sottoposti ad operazione di gastrectomia a 6 mesi dall'operazione. Sono stati reclutati 178 pazienti con obesità, e valutati 1 mese prima e 6 mesi dopo l'intervento di gastrectomia. Il protocollo di valutazione funzionale comprendeva test per la misurazione: della capacità cardiopolmonare, della forza muscolare, dell'equilibrio statico, del livello di attività fisica svolta e della qualità della vita. Dopo la chirurgia, 28 pazienti sono stati reclutati per 10 sessioni di esercizio fisico supervisionato.

Risultati

A seguito della chirurgia bariatrica, c'è stata una significativa diminuzione del peso, dell'indice di massa corporea e della circonferenza vita. La forza muscolare assoluta è diminuita, mentre la forza corretta per il peso è aumentata in modo significativo. L'equilibrio statico è migliorato nelle donne, mentre negli uomini tendeva a peggiorare. Dopo la chirurgia è migliorata la qualità della vita ed è aumentato il livello di attività fisica. Dopo il protocollo di esercizio fisico, i pazienti hanno migliorato la forza muscolare, l'equilibrio dinamico e la flessibilità.

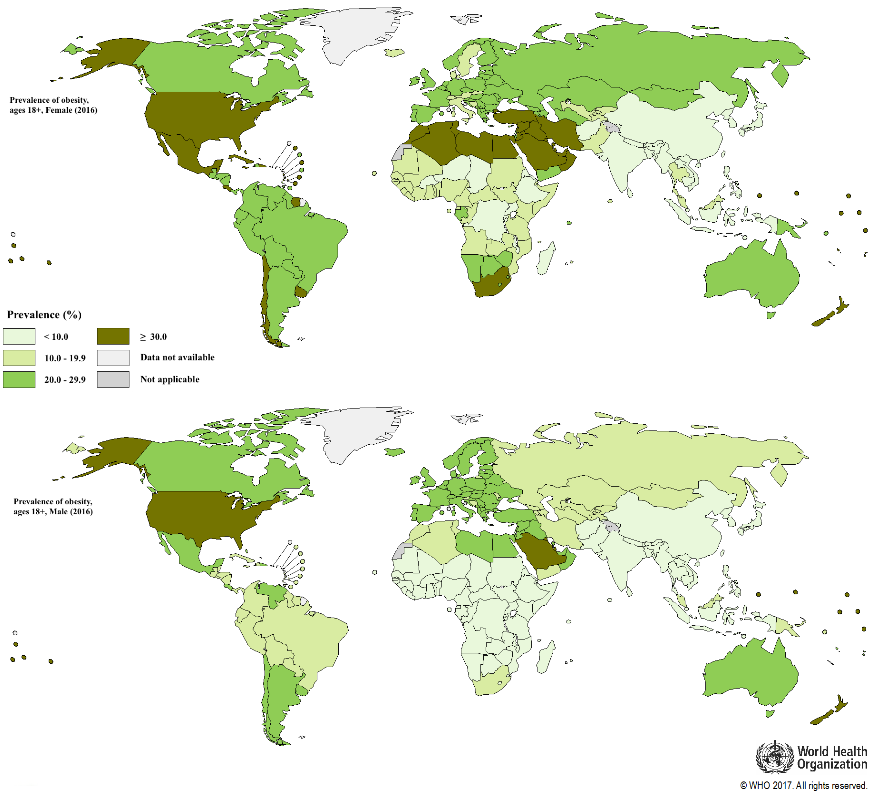
Conclusione

Anche se il calo ponderale è dovuto soprattutto all'operazione chirurgica, l'esercizio fisico è comunque strettamente raccomandato per contrastare la perdita di massa muscolare e migliorare la qualità della vita.

1. INTRODUCTION

Obesity is one of the greater public health problems of the 21st century, and it's considered as a worldwide epidemic [1]. The prevalence worldwide is tripled since 1975, and in 2016 11% of men and 15% of women was obese [2]. Except for sub-Saharan Africa and Asia, the global prevalence of people with obesity is major than people that are underweight (Fig. 1).

Fig. 1: worldwide obesity prevalence



Obesity is a chronic multifactorial pathology caused by environmental, behavioral and genetics factors [3], with negative impact on general health, quality of life, and increased risk to fall into disability and morbidity [4]. In fact, severe obesity is associated with hypertension, dyslipidemia, diabetes, and metabolic syndrome, such as musculoskeletal impairment that affect mobility and gait capacity [5]. Obesity is classified by the World Health Organization (WHO) by Body Mass Index (BMI), which is correlated with body fat mass [6]. Moreover, BMI is usually associated with waist circumference (WC) and waist-hip-ratio as indicator of abdominal obesity and cardiovascular risk (Tab. 1) [7].

Tab. 1: cardiovascular risk in relation to Body Mass Index and Waist Circumference

	BMI (kg/m^2)	**Men: WC ≤ 102cm** **Women: WC ≤ 88cm**	**Men: WC ≥ 102cm** **Women: WC ≥ 88cm**
Normal-weight	18.5 – 24.9	-----	-----
Overweight	25.0 – 29.9	Increased	High
Obesity I class	30.0 – 34.9	High	Very high
Obesity II class	35.0 – 39.9	Very high	Very high
Obesity III class	≥ 40	Extremely high	Extremely high

Abbreviation: BMI: body mass index; WC: waist circumference

Non-surgical management of obesity consists on a multicomponent approach, including behavioral therapy, pharmacotherapies, and lifestyle change to reduce the energy intake with diet, and increase physical activity [8]. Because few patients achieve an important weight loss with lifestyle change, many undergo to bariatric surgery [8]. Bariatric surgery is the most effective procedure for the management of obesity, with the greater body weight loss, and remission of several comorbidities such as type 2 diabetes mellitus, hypertension and dyslipidemia [9]. Moreover, bariatric surgery induces a consistent reduction of drugs use [10]. Bariatric surgery techniques could be divided into three categories: restrictive, primarily malabsorptive, and combined procedures.

The aim of restrictive procedures is to limit the solid food intake capacity. Some examples are adjustable gastric band, silicone adjustable gastric band, and laparoscopic silicone adjustable gastric bands. Adjustable gastric band consisted in the application of as adjustable ring around the stomach below the gastro-esophageal junction. Common postoperative complication includes gastric or esophageal perforation, infection, stoma obstruction, and hemorrhage [10]; the risk of mortality 30 days after surgery is about 0.08% [11]. Vertical sleeve gastrectomy consisted on stomach reduction about 80%. This restrictive surgery reduces the solid food intake capacity, inducing weight loss. Post-operative complications are staple line leak, bleeding, wound infection, splenic injury, and abscess [10]; mortality risk 30 day after surgery is about 0.24% [11]. Primarily malabsorptive techniques consisted in the reduction of intestinal mucosa involved for the nutrient absorption. Some examples are jejunoileal bypass, biliopancreatic diversion with duodenal switch, and mini gastric by-pass. The weight loss is induced primary by the reduction of area assigned of nutrient absorption with consequent reduction of calories' intake. Postoperative complications include diarrhea, electrolyte abnormality, macro- and/or micro-nutrient deficiency, and anemia [10]; the risk of mortality 30 day after surgery is about 0.9% [9]. Combined techniques get together primarily restrictive procedures with some malabsorption effect. Roux-en-y gastric bypass consisted on the stomach split into a small upper gastric pouch connected with the lower part of the bowel bypassing a major portion of the stomach and the upper part of the intestine. This operation induces a reduction of solid food intake capacity and absorption area. Postoperative complications are anastomotic leaks, bowel obstruction, bleeding, wound infection, deep vein thrombosis, and pulmonary embolism [10]; the risk of mortality 30 day after surgery is about 0.18% [11].

Even if the major effect of body weight loss is detected by bariatric surgery, pre- and post-surgery physical activity is suggested in patients with obesity. Before surgery, the American Society for Metabolic and Bariatric Surgery recommends 20 daily minutes of mild aerobic and strength exercises 3 times per week, to improve cardiorespiratory fitness and reduce the risk of surgical complications [12]. After bariatric surgery, a loss of fat free mass (FFM) was accounted about 31% of weight loss [13], with modification on functional capacity. Absolute strength tends to decrease, while relative increased [14]; static balance seems to improve [15], and physical activity level tends to increase [16]. Fat free mass accounts a significant part of resting metabolic rate, and lost on FFM seems to predispose weight regain in the long term [17]. For this reason, physical activity is strongly recommended in patients undergo bariatric surgery to maintain weight loss, contrast muscle mass lost, and avoid weight regain [13].

This study is divided into two phases. In the first phase, the aim is to evaluate functional capacity of patients with obesity before and after sleeve gastrectomy to analyzed changes of maximal oxygen consumption, muscular strength, static balance, level of physical activity and quality of life. In the second phase, the aim is to analyze the effect of 1 month supervised physical exercise protocol performed 6 months after surgery.

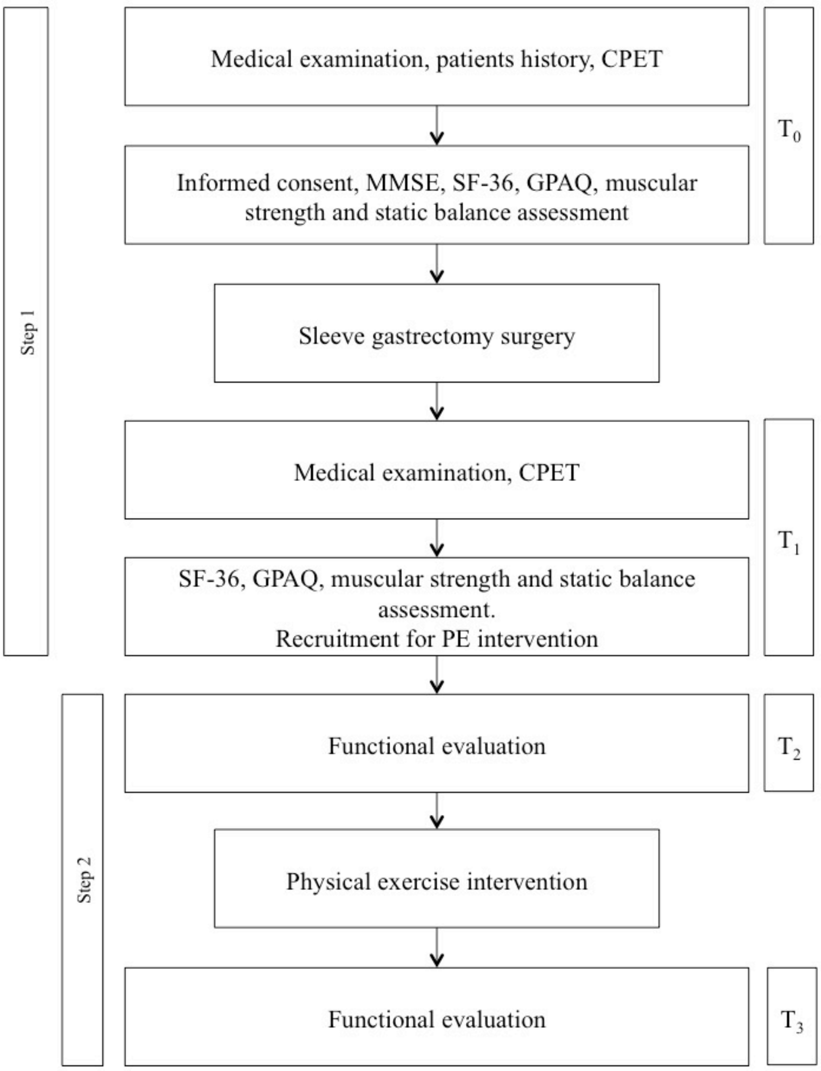
2. MATERIALS AND METHODS

2.1 Time-line of the project

The project was divided into 2 steps (Fig. 2).

1. Step one: evaluation of muscular strength, static balance capacity, level of physical activity and quality of life before (1 months) and after (6 months) sleeve gastrectomy (SG);
2. Step two: administration of a physical exercise protocol in patients 6 months after SG surgery.

Fig. 2: flow chart of the project



Abbreviation: CPET: cardiopulmonary exercise test; MMSE: mini-mental state examination; SF-36: short form health survey; GPAQ: global physical activity questionnaire; PE: physical exercise

2.2 Participants

2.2.1 First phase: pre- to post- sleeve gastrectomy analysis

For the first step, 179 patients (45 males and 134 females) with obesity, candidates for bariatric surgery, were recruited. Inclusion criteria were: a) BMI>35; b) undergo SG surgery within 1 months from the evaluation; c) no previous bariatric surgery; d) able to speak or understand Italian language; e) Mini Mental State Examination higher than 26. Exclusion criteria were: a) chronic conditions that could influence results (e.g. multiple sclerosis, history of cancer); b) no complete functional evaluation; c) other techniques of bariatric surgery different from sleeve gastrectomy.

2.2.2 Second phase: physical exercise intervention after sleeve gastrectomy

For the second step, 28 patients undergoing SG surgery, who expressed the interest to start a supervised physical exercise protocol, were recruited. The inclusion criterion was having undergone the surgery in the previous 7 months.

2.3 Evaluation protocol

2.3.1 Medical examination and cardiopulmonary exercise test

Medical examination and Cardiopulmonary exercise test (CPET) was administered by a Physician with Sport Medicine specialization. Participants' height and weight were measured with a stadiometer (Ayrton Corporation, Model S100, Prior Lake, MN) and an electronic scale (Home Health Care Digital Scale, Model MC-660, C-7300 v1.1), on the day of assessment. Moreover, waist circumference (WC) was recorded before and after surgery with a meter-stick.

Exercise capacity was assessed by an incremental electrocardiography-monitored CPET (Jaeger-Masterscreen-CPX, Carefusion, Germany). The test was performed conducing the modified-Bruce protocol on treadmill, until exhaustion monitored with Borg Rating of Perceived Exertion scale >18/20. Each patient performed the same test protocol 1 month before and 6 months after SG surgery. Heart rate, systolic blood pressure and diastolic blood pressure were monitored before, during and after CPET.

2.3.2 Mini Mental State Examination

The mini mental state examination was administered to all participants at the first visit (before surgery). This tool was used to identify cognitive impairment [18], and to exclude subjects with a result lower than 26.

2.3.3 Muscular strength assessment

Dominant and non-dominant isometric grip strength (HG) was evaluated with a calibrated dynamometer (Baseline, Elmsford, NY, USA). The test was performed in sitting position. The grip handle was adapted to the hand size for a comfortable grab, the elbow was flexed at 90° and adheres to the body to guarantee the strongest grip measures [19]. Three trials per hand were collected, and the mean of the dominant hand was used to identify the percentile.

Lower limb muscular strength was evaluated with the multi-joint evaluation system Prima Plus (Easytech, Italy). Patients were seated with the backrest angled at 90°. Belts were placed around the thighs to isolate the movement of knee and ankles during the evaluation. The protocol included the evaluation of isometric bilateral knee extension muscular strength, and isokinetic bilateral knee extension and flexion muscular strength. In both tests, the fulcrum of the lever was aligned with the rotation axis of the knee, and the shin pad was positioned 2cm above the medial malleoli. The 0° corresponded to the maximal personal extension of the knee, and the lever was set at 75° of flexion. During the isometric evaluation, patient had to kick against the two pads and maintained the maximal isometric contraction for 5 seconds. The trial was performed 3 times, with 60 second of restore among them. In the isokinetic test, the weight of the legs was noted and a gravity adjustment was made using the computer software. The patient had to perform a maximal extension and flexion of the knee for 5 times consecutively, without pause between the two movements and the velocity seated at 90°/sec. The trial was performed 3 times, with 60 seconds of restore among them. The parameters recorded were:

- Maximal isometric strength: mean of the 3 peak of force
- Average isometric strength: mean of the average strength expressed during the 5 seconds of the test
- Maximal isokinetic strength in extension: mean of the 3 peak of force in extension
- Maximal isokinetic strength in flexion: mean of the 3 peak of force in flexion

The protocol was previously validated in elderly [20] and young [21] subjects.

2.3.4 Static balance assessment

Static balance was measured with the ARGO stabilometric platform (RGMD, Genoa, Italy). The evaluation of static balance was performed in two conditions: open eyes, and closed eyes. In both tests, subjects were required to stand in upright position with feet together and the arms at sides as still as possible. During the Romberg test with eyes open, the subject had to stare a reference point located on the blackboard for 30 seconds. During the Romberg test with eyes closed, the subject had to stay on the platform for 30 seconds with closed eyes. In both the trials, were recorded four parameters:

- Sway Path (SP): center of pressure (CoP) velocity.
- Sway Area (SA): the shape that include the 95% of the CoP displacement.
- Anterior-posterior oscillation (APO): the maximal displacement of the CoP in antero-posterior directions.
- Medio-lateral oscillation (MLO): the maximal displacement of the CoP in medio-lateral directions.

These measures were collected at 100 Hz sampling rate.

2.3.5 Global Physical Activity Questionnaire

Physical activity level was evaluated with Global Physical Activity Questionnaire (GPAQ). It collected information about physical activity performed at work, to travel to and from place, and in the leisure time. Moreover, it recorded the daily time spent in sedentary behaviors [22]. The questionnaire was self-administered, and verified by an operator later.

For the analysis, was performed the conversation of weekly minutes of physical activity in leisure time in METs, following the GPAQ guidelines. In details, moderate activity was multiplied by 4, vigorous activity was multiplied by 8, and later the two values were added up [22]. Subjects who achieved 600 weekly METs were classified as "active", who performed less than 600 METs were classified as "no sufficiently active", while a value of 0 corresponded to "sedentary" subjects.

2.3.6 Short Form Health Survey

The Short Form Health Survey (SF-36) is a 36-item questionnaire that measures the health status. It's divided into 8 scales that composed two domains:

- Physical health summary (PCS): physical functioning (PF), physical role functioning (RP), bodily pain (BP), and general health perceptions (GH).
- Mental health summary (MCS): vitality (VT), social role functioning (SF), emotional role functioning (RE), and mental health (MH).

2.3.7 Functional evaluation

Subjects who took part in the physical exercise program were evaluated using functional tests included in the Senior Fitness Test [23]:

- 30-second chair stand test (30CST): this test assesses lower body strength. The subjects had to set in the middle of a chair with back straight, feet flat on the floor, and arms cross at the wrists and held against the chest. At the signal "go", the participants had to full stand up and returned to a seated position consecutively. The aim was to complete as many as possible full stands correctly in 30 seconds. If the participant is more than halfway up at the end of the 30 seconds, it counts as a full stand.

- 30-second arm curl test (30ACT): this test assesses upper body strength. The subjects had to set on a chair with back straight, feet flat on the floor, and the dominant side of the body close to the side edge of the chair, with a weight (2 kg) grasped with the dominant hand. At the signal “go”, the participants had to curl flex the arm through the entire range of motion and returned to the full extension consecutively. The aim was to complete as many as possible full curls correctly in 30 seconds. If the arm is more than halfway up at the end of the 30 seconds, it counts as a curl.
- Chair sit-and-reach test (SRT): this test assesses the lower body flexibility, primarily hamstrings. The participants had to sit on a chair and move forward until the front edge. One leg was bent with the foot flat on the floor, while the other was extended in front, with the heel on floor and foot flexed at approximately 90°. With the two hands put one on top of the other, the subjects had to slowly bends forward sliding the hands above the extended leg. The reach must be held for 2 seconds, and the distance between the toe and the end of the middle fingers was recorded.
- Back scratch (BS): this test assesses the upper body flexibility, primarily shoulders. In standing position, the participants had to places the dominant hand behind the same-side shoulder, palm toward back and fingers extended, reaching down the middle of the back as far as possible. The other hand was placed behind the back, palm out, reaching up as far as possible in an attempt to touch or overlap the extended middle fingers of the both hands. The distance of overlap or distance between the tips of the middle fingers is measured. The minus score (-) is given to represent a distance short of touching; a plus score (+) represents the amount of an overlap.
- 8-foot up-and-go (8F-UG): this test assesses agility and dynamic balance. The chair must be positioned against a wall or in some other way that could impede movement during the test. A cone is positioned in front of it with a distance of 2.44 meters. The test beginning with the subject seated in the chair, hands on the thighs and feet flat on the floor. On the signal “go” the subjects gets up, walks as quickly as possible (without running) around the cone, and returns to the chair. The score is the time from the signal “go” and the participant returns to a seated position.

2.4 Physical exercise protocol

The physical exercise protocol consisted on 10 sessions of personal training performed 2 times per week and lasting 60 minutes. Before starting, each subject had a meeting with an exercise specialist and performed the functional evaluation's tests. The same tests were performed during the 10^{th} exercise sessions. All sessions were divided into warm-up, main training, and cool-down. Before and after each session blood pressure were recorded on subjects with hypertension. Warm-up exercise included joint mobility and aerobic exercise (10-15 minutes). The main training (30-40 minutes) included primarily muscular strength exercise performed as circuit training to reduce recovery time. The program included exercise for the main muscular group (quadriceps, hamstrings, pectoral muscles, dorsal muscle, arm, abdomen muscles). Moreover, specific balance training was added in subjects with balance impairments. Finally, a cool-down phase was performed with aerobic and stretching exercise to restore muscles training during the session (10-15 minutes).

The protocol scheduled a volume and intensity progression increasing weight, or substituted the elastic bands with free weight or machine (Tab. 2).

2.5 Statistical analysis

Two statistical analyses were conducted with SPSS (Version 21.0 for Windows, SPSS Inc., Chicago, IL). Data are presented as mean ± standard deviation. For the first analysis, Shapiro-Wilk test was applied to check the normal distribution of all the variables. The comparison between pre- to post-SG was performed with paired t test for normally distributed variables; otherwise, the Wilcoxon-Mann-Whitney was performed. Pearson's correlation coefficient (ρ) was calculated between pre- to post-SG functional capacity and clinical outcomes (e.g. weight loss, BMI loss, WC loss, …). The correlation coefficient ranges from -1 to +1. A value of 1 implies the perfect linear relationship between the two variable X and Y, while a 0 value indicates no correlation. A value of $p < 0.05$ was considered statistically significant.

For the second analysis, student's t test for dependent samples was used to evaluate within group difference before versus after physical exercise intervention. Significance limits were set at $p < 0.05$ and results are expressed as mean ± standard deviation (SD).

Tab. 2: general characteristics of physical exercise protocol

	Physical capacity	Type of exercise	Duration, repetition, series
Warm-up	Joint mobility	Cervical spine, shoulder, dorsal spine, low spine, hip, ankle	10 repetitions
	Aerobic capacity	Bike, treadmill, cross-trainer	10-20 minutes
Main part	Upper body muscular strength	Pulley, French press, push-up, pull down, lat machine, bench press, push down, chest press	15 repetitions, 2 series
	Lower body muscular strength	Mono- or bi-lateral leg extension, step up, leg press, leg curl, gluteus bridge, lunges, squat with Fit-ball, standing calf, deadlifts	Mono: 6-8 repetitions Bi: 10-15 repetitions 2 series
	Abdominal, back muscular strength	Crunch, superman plank, plank	10-15 repetitions 2 series
	Balance and proprioception	Speed ladder, walking on foam surface, mono-lateral balance	30 seconds 5 minutes
Cool-down	Aerobic capacity	Bike, treadmill, cross-trainer, walking	5-15 minutes
	Muscular flexibility	Stretching exercise for hamstrings, low back, pectorals	30 seconds 5-10 minutes

Abbreviation: mono: mono-lateral; bi: bilateral

3. RESULTS

The same evaluation protocol was used before and after SG. Height and weight were used to calculate body mass index (BMI). Moreover, the percentage of Excess BMI Loss (%Ex-BMI-L) was calculated to determine the success of surgery.

3.1 Physical capacity before and after sleeve gastrectomy

For the first step, 179 obese patients (45 males and 134 females) were recruited 1 month before SG surgery. Sixteen patients (3 males and 12 females) were excluded for previous bariatric interventions, and 5 females because mini-by-pass bariatric surgery where performed. The analysis was applied to 159 obese patients (42 males, 117 females). Baseline characteristics are reported into (Tab. 3).

No comorbidities were recorded into 10% of males and 19% of females. Pre-diabetes was present in 21% of males and 15% of females, while 21% of males and 18% of females were diabetic. Hypertension was present in 50% of males and 39% of females, obstructive sleep apnea syndrome affected 48% of males and 10% of females, while dyslipidemia had an incidence of 24% in both sexes. Finally, 5% of males and 22% of females had hypothyroidism.

Tab. 3: baseline participants' characteristics before sleeve gastrectomy surgery (mean ± standard deviation)

	Males (42)	**Females (117)**
Age (years)	45.07 ± 10.47	44.87 ± 10.99
Height (m)	1.77 ± 0.07	1.61 ± 0.07
Weight (kg)	142.77 ±19.88	114.64 ± 16.92
BMI (kg/m^2)	45.7 ± 7.06	43.91 ± 5.52
WC (cm)	142.41 ± 13.27	126.15 ± 13.08
MMSE (score)	29.19 ± 1	29.12 ± 1.08
Comorbidities (type)	Pre-diabetes (9), DMT2 (9), hypothyroidism (2), dyslipidemia (10), IPTS (21), OSAS (19), musculoskeletal disorders (12), other (31)	Pre-diabetes (17), DMT2 (21), hypothyroidism (26), dyslipidemia (28), IPTS (46), OSAS (12), musculoskeletal disorders (39), other (56)
Comorbidities (num)	No com. (4), 1 com. (9), 2 com. (10), 3 com. (9), 4 com. (5), 5 com. (3), >6 com. (1)	No com. (22), 1 com. (29), 2 com. (21), 3 com. (19), 4 com. (16), 5 com. (7), >6 com. (3)
Drugs (num)	No drug (16), 1 drug (8), 2 drugs (3), 3 drugs (6), 4 drugs (3), 5 drugs (2), >6 drugs (1)	No drug (33), 1 drug (27), 2 drugs (22), 3 drugs (11), 4 drugs (7), 5 drugs (8), >6 drugs (2)
Class of obesity (%)	II class obesity: 11 (26%) III class obesity: 31 (74%)	II class obesity: 34 (29%) III class obesity: 83 (71%)

Abbreviation: BMI: body mass index; WC: waist circumference; MMSE: mini mental state examination; II class obesity: BMI 35-39.9; III class obesity: BMI >40; DMT2: type 2 diabetes mellitus; IPTS: hypertension; OSAS: obstructive sleep apnea syndrome; num: number; com; comorbidities

3.1.1. Anthropometric parameters and cardiopulmonary capacity

The success of bariatric surgery is commonly accepted as a % of excess BMI loss (%Ex-BMI-L) higher than 50%. After 6 months, the mean %Ex-BMI-L was 67.3% in males and 63.4% in females. Moreover, 85.7% of males and 76.9% of females lost more than 50% of Excess BMI.

As expected, after bariatric surgery was found a significant decrease of body weight, BMI, and WC in both groups. Moreover, male sample recorded higher decrease than females in body weight (-28.6% vs -26%), BMI (-28.7% vs -26%), and WC (-21.4% vs -15.2%) (Tab. 4).

Tab. 4: changes of anthropometric parameters after SG

		Males (m±sd)	Males (Δ; %)	Females (m±sd)	Females (Δ, %)
Age (y)		45.07±10.47		44.87±10.99	
Height (m)		1.77±0.07		1.61±0.07	
Weight (kg)	Pre	142.77±19.88	-40.8 kg	114.64±16.92	-29.8 kg
	Post	101.95±17.23**	-28.6%	84.82±13.9**	-26%
BMI (kg/m^2)	Pre	45.7±7.06	-13.1	43.91±5.52	-11.4
	Post	32.59±5.6**	-28.7%	32.5±4.66**	-26%
WC (cm)	Pre	142.41±13.27	-30.5 cm	126.15±13.08	-18.7 cm
	Post	111.95±13.4**	-21.4%	104.01±11.8**	-15.2%
%Ex-BMI-L	>50%	36 patients	85.7%	90 patients	76.9%
	<50%	6 patients	14.3%	27 patients	23.1%

Abbreviation: BMI: body mass index; WC: waist circumference; %Ex-BMI-L: percentage of excess body mass index loss; m±sd: mean ± standard deviation; Δ: change from post to pre; * p<0.05; ** p<0.001

Pearson's correlation coefficient (ρ) was calculated between pre-SG functional capacity and weight loss, BMI loss, and %Ex-BMI-L (Tab. 5). Statistical analysis showed a negative moderate correlation between weight loss and age (ρ = -0.31 M, ρ = -0.49 F). On the contrary, weight loss was positively moderately correlated with pre-surgery body weight (ρ = 0.5 M, ρ = 0.6 F), while WC was positive correlated only in male sample (ρ = 0.37). Pre-surgery absolute muscle strength was correlated only in females; in details, dominant and non-dominant hand showed a small positive correlation (ρ = 0.22, ρ = 0.28), while isometric strength of knee extensors showed a positive moderate correlation (ρ = 0.36). Moreover, also absolute maximal oxygen consumption was positive moderate correlated with weight loss (ρ = 0.51) in females. In regards to %Ex-BMI-L, correlation analysis showed negative moderate correlation with age (ρ = -0.34 M, ρ = -0.3 F), while a positive moderate correlation was found with relative VO_{2max} (ρ = 0.5 M, ρ = 0.53 F). Moreover, WC was negative moderate correlated in female sample (ρ = -0.32), while male sample showed a strong negative correlation (ρ = -0.72).

Tab. 5: correlation between weight loss, BMI loss, %Ex-BMI-L and pre-surgery physical capacity (only statistically significant value are reported)

		WL (kg)	**Δ BMI (pt)**	**%Ex-BMI-L**
Age (y)	Males	-0.31*		-0.34*
	Females	-0.49**	-0.44**	-0.3**
Weight (kg)	Males	+0.5**	+0.44**	-0.6**
	Females	+0.6**	+0.46**	-0.48**
WC (cm)	Males	+0.37*	+0.4*	-0.72**
	Females			-0.32**
Dominant HG (kg)	Males			
	Females	+0.22*		
Non-dominant HG (kg)	Males			
	Females	+0.28**		
Isometric Fmax (Nm)	Males			
	Females	+0.36**	+0.31**	+0.27*
VO_{2max} (ml/kg/min)	Males		-0.39*	+0.5**
	Females			+0.53**
VO_{2max} (L/min)	Males			
	Females	+0.51**	+0.36**	

Abbreviation: WL: weight loss; BMI: body mass index; %Ex-BMI-L: percentage of excess BMI loss; WC: waist circumference; HG: handgrip; Fmax: maximal strength; VO_{2max}: maximal oxygen consumption; Δ: change from post to pre; * p<0.05; ** p<0.001

Maximal oxygen consumption (VO_{2max}) was analyzed as absolute value (L/min) and relative to body weight (ml/kg/min) (Tab. 6)

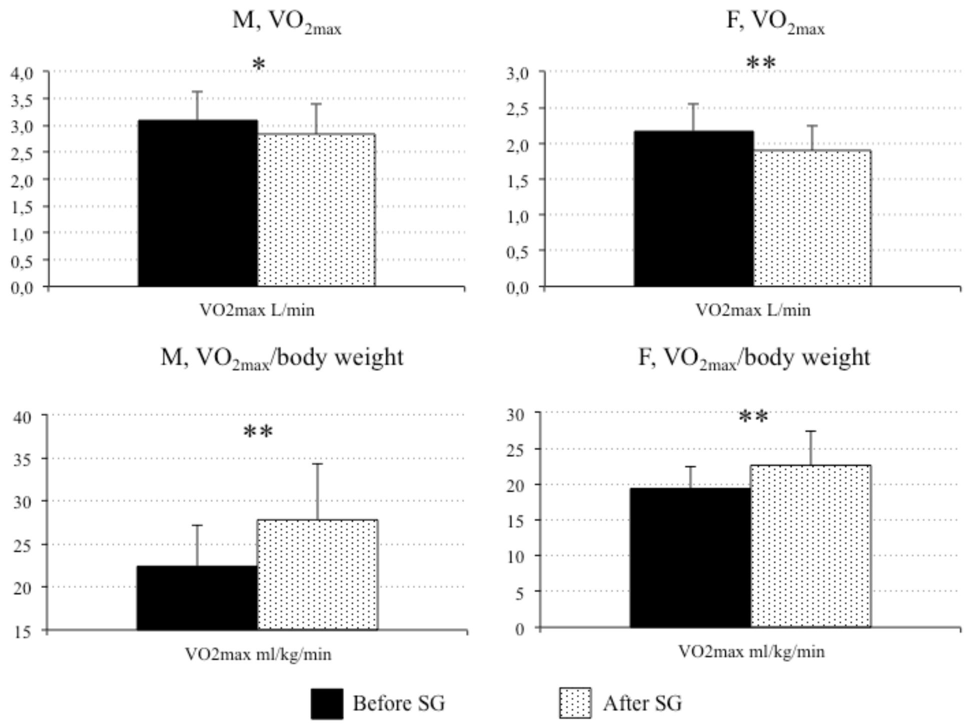
Tab. 6: VO_{2max} before and after SG

		Males (m±sd)	Males (Δ; %)	Females (m±sd)	Females (Δ, %)
VO_{2max} (L/min)	Pre	3.1±0.5	-0.3 L/min	2.2±0.4	-0.3 L/min
	Post	2.8±0.6*	-8.8%	1.9±0.3**	-12.6%
VO_{2max} (ml/kg/min)	Pre	22.5±4.7	+5.4 ml/kg/min	19.3±3.2	+3.3 ml/kg/min
	Post	27.9±6.4**	+24%	22.5±4.8**	+16.9%

Abbreviation: VO_{2max}: maximal oxygen consumption; m±sd: mean ± standard deviation; Δ: change from post to pre; * $p<0.05$; ** $p<0.001$

Absolute VO_2max decreased significantly after SG in both male (-8.8%) and female (-12.6%) subjects. On the contrary, relative VO_{2max} increased significantly (+24% in males and +16.9% in females).

Fig. 3: absolute and relative VO_{2max} before and after SG



Abbreviation: VO_{2max}: maximal oxygen consumption; M: male; F: female; SG: sleeve gastrectomy; * $p<0.05$; ** $p<0.001$

Pearson's correlation coefficient (ρ) was calculated between absolute change from pre- to post-surgery and pre surgery functional capacity. Analysis of VO_{2max} and isokinetic muscular strength showed positive small correlation with strength of knee extensors ($\rho = 0.29$, $p < 0.05$) and moderate positive correlation with strength of knee flexors ($\rho = 0.3$, $p < 0.001$) in females, evaluated before surgery. No other significant correlation was found.

3.1.2. Muscular strength

Upper and lower limb muscular strength were analyzed as absolute value and corrected for body weight.

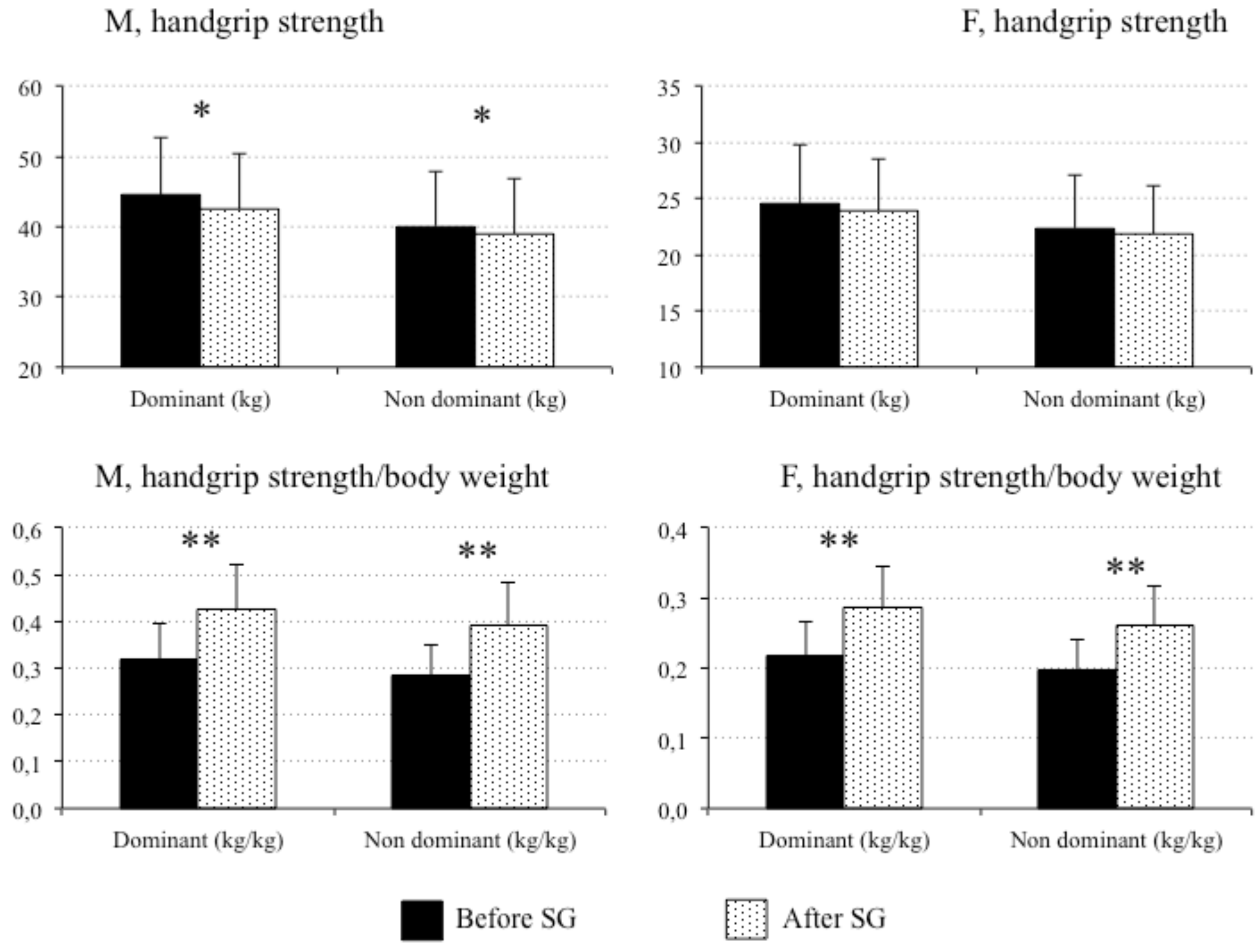
Tab. 7: muscle strength of upper limb before and after SG

		Male (m±sd)	Male (Δ; %)	Female (m±sd)	Female (Δ, %)
Dominant HG (kg)	Pre	44.5±8.2	-1.9	22.4±4.7	-0.6
	Post	42.6±7.9**	-4.4%	21.8±4.4	-2.4%
Non-dominant HG (kg)	Pre	40.1±7.9	-1.1	22.4±4.7	-0.6
	Post	39.0±7.9*	-2.7%	21.8±4.4	-2.6%
Dominant HG (kg/kg)	Pre	0.3±0.1	+0.1	0.2±0.0	+0.1
	Post	0.4±0.1**	+34.1%	0.3±0.1**	+32.1%
Non-dominant HG (kg/kg)	Pre	0.3±0.1	+0.1	0.2±0.0	+0.1
	Post	0.4±0.1**	+36.8%	0.3±0.1**	+32%

Abbreviation: HG: handgrip; m±sd: mean ± standard deviation; Δ: change from post to pre; kg/kg: handgrip strength / body weight; * p<0.05; ** p<0.001

Upper limb muscular strength evaluated with handgrip test showed a reduction of absolute strength (kg) of dominant and non-dominant hand in both sexes (Tab. 7). In details, male subjects worsened their strength of dominant (-4.4%, p<0.05) and non-dominant (-2.7%, p<0.05) hand; while females recorded a reduction of dominant (-2.4%) and non-dominant (-2.6%) hand without statistical significance. Handgrip strength corrected for body weight, showed significant improvement in both dominant and non-dominant hand, in both sexes. Male improved by 34.1% and 36.8% for dominant and non-dominant hand, while in females strength increased by 32.1% and 32% (Fig. 4).

Fig. 4: absolute and relative handgrip test before and after SG



Abbreviation: M: male; F: female; SG: sleeve gastrectomy; m±sd: mean ± standard deviation; Δ: change from post to pre; kg/kg: handgrip strength / body weight * p<0.05; ** p<0.001

Lower limb muscular strength didn't show significant changes in both isometric and isokinetic strength. In details, maximal and mean isometric strength improved after SG in female group (+1.1%, +4.7%); while in males was found a decrease in both parameters (-4.3%, -0.6%). On the contrary, isokinetic strength improved in males and decrease in females. In details, isokinetic strength improved by +1.7% during the extension movement and +3,1% during the flexion movement. In female subjects, isokinetic strength during extension decreased by -0.9%, while flexion recorded a decrease about -1.1% (Tab. 8).

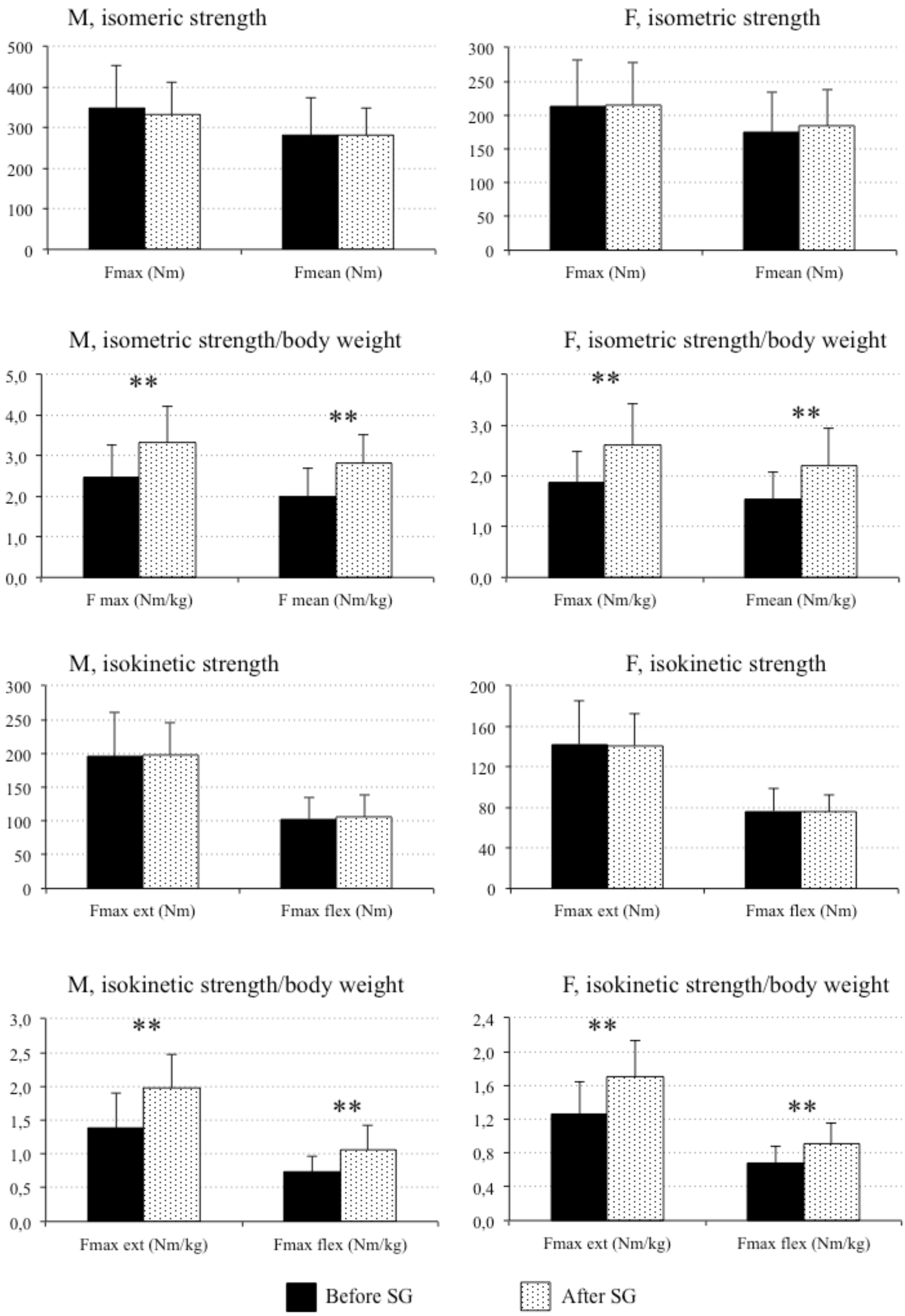
Similarly to upper limb strength, also the strength of lower limb corrected for body weight were significantly higher 6 months after SG. Maximal and mean isometric strength corrected by body weight increase by +34.9% and +39.9% in male, and +38% and +42.9% in female. Isokinetic strength corrected by body weight increased by 42.7% (extension) and 45.3% (flexion) in male group, while females improved their isokinetic strength by 34.8% in both extension and flexion movements (Fig. 5).

Tab. 8: muscle strength of lower limb before and after SG

		Male (m±sd)	Male (Δ; %)	Female (m±sd)	Female (Δ, %)
Isometric Fmax (Nm)	Pre	347.6±106.4	-14.8	213.0±67.7	+2.4
	Post	332.8±77.9	-4.3%	215.4±61.9	+1.1%
Isometric Fmean (Nm)	Pre	282.3±91.3	-1.6	175.3±58.4	+8.2
	Post	280.8±67.6	-0.6%	183.4±54.2	+4.7%
Isokinetic Fmax ext (Nm)	Pre	194.9±66.6	+3.3	142.3±43.2	-1.3
	Post	198.2±46.5	+1.7%	141.0±31.2	-0.9%
Isokinetic Fmax flex (Nm)	Pre	102.9±32.0	+3.1	76.4±22.4	-0.9
	Post	106.0±33.4	+3.1%	75.5±17.4	-1.1%
Isometric Fmax (Nm/kg)	Pre	2.5±0.8	+0.9	1.9±0.6	+0.7
	Post	3.3±0.9**	+34.9%	2.6±0.8**	+38%
Isometric Fmean (Nm/kg)	Pre	2.0*±0.7	+0.8	1.6±0.5	+0.7
	Post	2.8±0.7**	+39.9%	2.2±0.7**	+42.9%
Isokinetic Fmax ext (Nm/kg)	Pre	1.4±0.5	+0.6	1.3±0.4	+0.4
	Post	2.0±0.5**	+42.7%	1.7±0.4**	+34.8%
Isokinetic Fmax ext (Nm/kg)	Pre	0.7±0.2	+0.3	0.7±0.2	+0.2
	Post	1.1±0.4**	+45.3%	0.9±0.2**	+34.8%

Abbreviation: Nm: Newton meter; Fmax: maximal strength; Fmean: mean strength 5seconds; ext: extension; flex: flexion; m±sd: mean ± standard deviation; Δ: change from post to pre; Nm/kg: Newton meter / body weight; * p<0.05; ** p<0.001

Fig. 5: absolute and relative isometric and isokinetic muscular strength before and after SG



Abbreviation: Fmax: maximal strength; Fmean: mean strength 5seconds; ext: extension; flex; flexion; M: male; F: female; SG: sleeve gastrectomy; Nm/kg: Newton meter / body weight; * $p<0.05$; ** $p<0.001$

Pearson's correlation coefficient (ρ) was calculated between:

- baseline muscle strength, VO_{2max} and anthropometric parameters (Tab. 9)
- muscle strength changes, weight loss, and VO_{2max} change

Pre-surgery, only dominant and non-dominant handgrip strength of females had positive moderate correlation with body weight (ρ = 0.22, ρ = 0.29). Moreover, also VO_{2max} had positive moderate correlation (ρ = 0.42). In both sexes, all strength tests had positive moderate correlation with absolute VO_{2max} (Tab. 9).

Tab. 9: correlation between pre-surgery physical capacity, body weight and VO_{2max} (only statistically significant value are reported)

		Body weight (kg)	**VO_{2max} (L/min)**
Dominant HG (kg)	Males		+0.33*
	Females	+0.22*	+0.35**
Non-dominant HG (kg)	Males		+0.34*
	Females	+0.29**	+0.36**
Isometric Fmax (Nm)	Males		+0.4*
	Females		+0.47**
Isometric Fmean (Nm)	Males		+0.44*
	Females		+0.48**
Isokinetic Fmax ext (Nm)	Males		+0.41*
	Females		+0.51**
Isokinetic Fmax flex (Nm)	Males		+0.5**
	Females		+0.44**
VO_{2max} (L/min)	Males		
	Females	+0.42**	

Abbreviation: Fmax: maximal strength; Fmean: mean strength 5seconds; ext: extension; flex; flexion; VO_{2max}: maximal oxygen consumption; * $p<0.05$; ** $p<0.001$

No correlation was found between weight loss and difference between pre-to post surgery values of muscular strength. Positive moderate correlation was found between absolute change of VO_{2max} and change isokinetic muscle strength of extensors (ρ = 0.45, $p < 0.05$) in males; while in female patients a small positive correlation was found with change of non-dominant HG (ρ = 0.19, $p < 0.05$).

3.1.3. Static balance

Static balance was evaluated with stabilometric platform in two different conditions: eyes opened (EO) and eyes closed (EC) (Tab. 10).

Tab. 10: static balance before and after SG

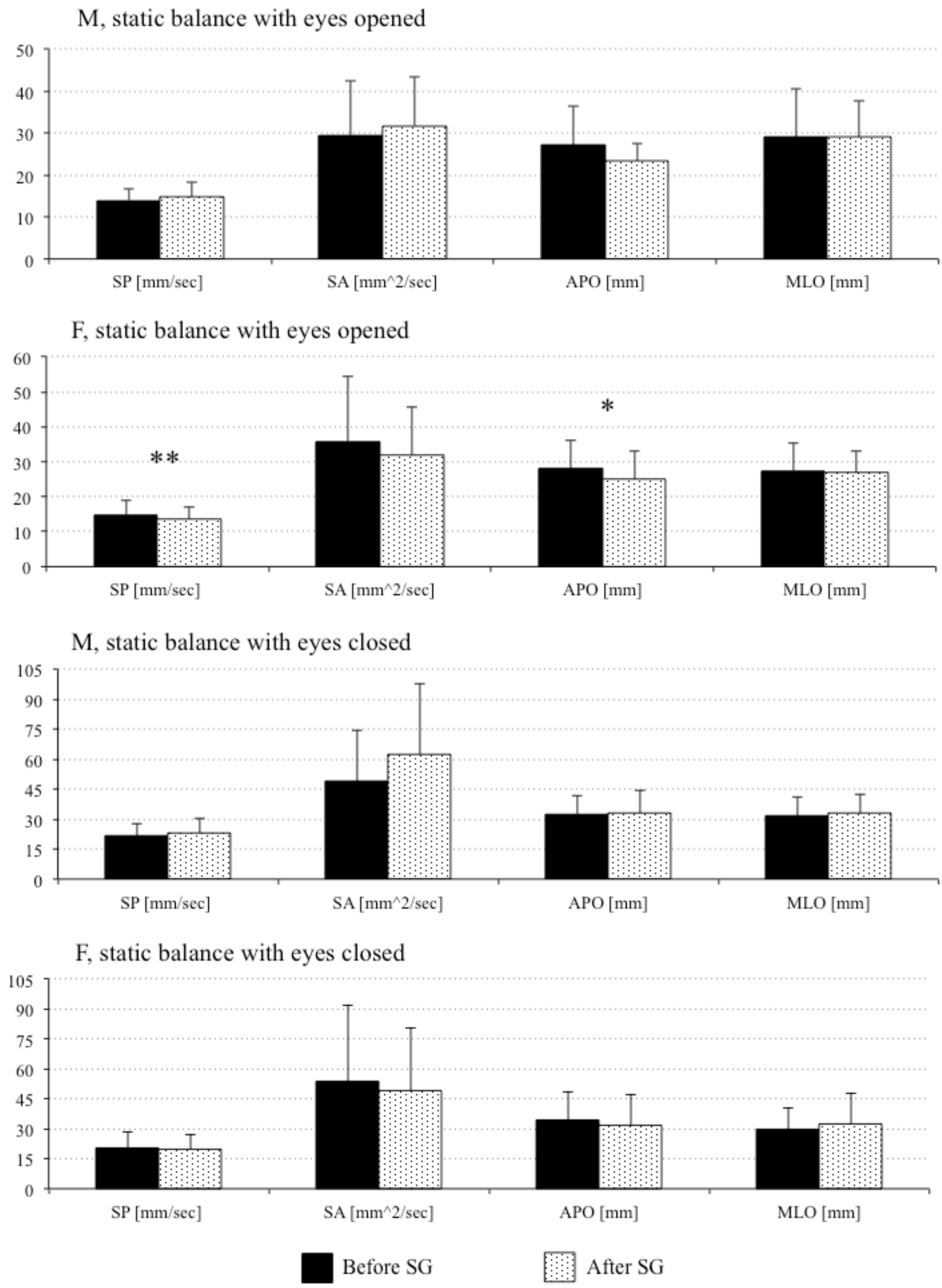
		Males (m±sd)	Males (Δ)	Females (m±sd)	Females (Δ)
SP (mm/sec) Eyes opened	Pre Post	14.0±2.6 14.7±3.6	+0.7 mm/sec	14.8±4.0 13.5±3.4**	-1.2 mm/sec
SA (mm^2/sec) Eyes opened	Pre Post	29.5±13.0 31.8±11.8	+2.3 mm/sec^2	35.8±18.4 31.9±13.9	-4.0 mm/sec^2
APO (mm) Eyes opened	Pre Post	27.1±9.4 23.4±4.0	-3.7 mm	27.9±8.2 25.0±8.0*	-2.9 mm
MLO (mm) Eyes opened	Pre Post	29.1±11.3 29.0±8.8	-0.1 mm	27.4±7.9 26.8±6.2	-0.6 mm
SP (mm/sec) Eyes closed	Pre Post	21.5±6.4 23.2±7.1	+1.7 mm	20.5±8.1 19.7±7.2	-0.8 mm
SA (mm^2/sec) Eyes closed	Pre Post	48.9±25.5 62.3±35.7	+13.3 mm	54.0±37.9 49.2±31.0	-4.8 mm
APO (mm) Eyes closed	Pre Post	32.7±9.4 32.9±11.3	+0.2 mm	34.6±13.9 31.7±15.5	-2.9 mm
MLO (mm) Eyes closed	Pre Post	31.7±9.2 33.1±9.6	+1.4 mm	30.0±10.3 32.7±15.3	+2.8 mm

Abbreviation: SP: sway path; SA: sway area; APO: antero-posterior oscillation; MLO: medio-lateral oscillation; M: male; F: female; m±sd: mean ± standard deviation; Δ: change from post to pre; * $p<0.05$; ** $p<0.001$

After SG, static balance improved in female group, with significant decrease of SP (-1.2 mm/sec) and APO (-2.9 mm^2/sec). No significant changes were found in male group, which presented an increase of SP (+0.7 mm/sec) and SA (+2.3 mm^2/sec), while APO (-3.7 mm) and MLO (-0.1 mm) decreased.

Static balance evaluated with eyes closed showed no significant changes in both groups. In females, results showed a reduction of SP (-0.8 mm/sec), SA (-4.8 mm^2/sec), and APO (-2.9 mm), while MLO increased (+2.8 mm). On the contrary, male group demonstrated a worsening in all the parameters (SP +1.7 mm/sec; SA + 13.3 mm^2/sec; APO +0.2 mm; MLO +1.4 mm) (Fig. 6).

Fig. 6: static balance before and after SG



Abbreviation: SP: sway path; SA: sway area; APO: antero-posterior oscillation; MLO: medio-lateral oscillation; M: male; F: female; SG: sleeve gastrectomy; * $p<0.05$; ** $p<0.001$

Pearson's correlation coefficient (ρ) was calculated between:

- Baseline anthropometric parameters, lower limb muscle strength and static balance (Tab. 11)
- Change between pre- to post-surgery oscillations, weight loss, and change of muscle strength (Tab. 12).

Anthropometric parameters influenced static balance only in female group, with small negative correlation between body weight and SP (ρ = -0.22) and MLO (ρ = -0.23). In male group, maximal isometric muscle strength had strong correlation with APO (ρ = 0.79), and moderate positive correlation with MLO (ρ = 0.66) (Tab. 10).

Tab. 11: correlation between baseline anthropometric parameters, lower limb muscle strength and static balance (only statistically significant value are reported)

	SP (mm/sec)	SA (mm/sec^2)	APO (mm)	MLO (mm)
Body weight (kg)	-0.22* (F)			-0.23* (F)
Isometric Fmax (Nm)			+0.79** (M)	+0.66* (M)

Abbreviation: SP: sway path; SA: sway area; APO: antero-posterior oscillation; MLO: medio-lateral oscillation; Fmax: maximal strength; M: male; F: female; * $p<0.05$; ** $p<0.001$

In regards to pre- to post- surgery modifications of static balance, significant correlation was found only for open eyes condition. In males, strong positive correlation was found between age, SP (ρ = 0.75) and SA (ρ = 0.71) changes. Moreover, significant strong correlation was found between change in AP oscillations and change of isometric maximal muscle strength of knee extensors (ρ = 0.86). In regards to %Ex-BMI-L, SP was negative moderate correlated (ρ = -0.61), and SA was negative strongly correlated (ρ = -0.72). In females, only change in APO had moderate positive correlation with maximal isokinetic muscle strength of knee extensors (ρ = 0.32). No significant correlation was found for ML oscillation (Tab. 12).

Tab. 12: correlation between change of static balance, weight loss, and change of muscle strength (only statistically significant value are reported)

	Δ SP (mm/sec)	**Δ SA (mm/sec^2)**	**Δ APO (mm)**	**Δ MLO (mm)**
Age (y)	+0.75** (M)	+0.71** (M)		
%Ex-BMI-L	-0.61* (M)	-0.72** (M)		
Δ Isometric Fmax (Nm)			+0.86** (M)	
Δ Isokinetic Fmax (Nm)			+0.32** (F)	

Abbreviation: M: male; F: female; Fmax: maximal strength; ext: extension; flex; flexion; Δ: change from post to pre; * $p<0.05$; ** $p<0.001$

3.1.4. Level of physical activity

The analysis of weekly METs of physical activity of leisure time showed that 51% of males and 53% of females were sedentary before surgery. The percentage of males that achieved the minimal recommended level of physical activity was 29%, while 20% were no sufficiently active. Similarly, 23% of females were active before surgery, while 25% were no sufficiently active (Tab.13).

After SG, 55% of patients increased their energy expenditure in leisure time, 37% maintained the pre-surgery level of physical activity, and 8% decrease the amount of physical activity. Moreover, the analysis of weekly METs used for leisure physical activity showed significant improvement only for activity with moderate intensity.

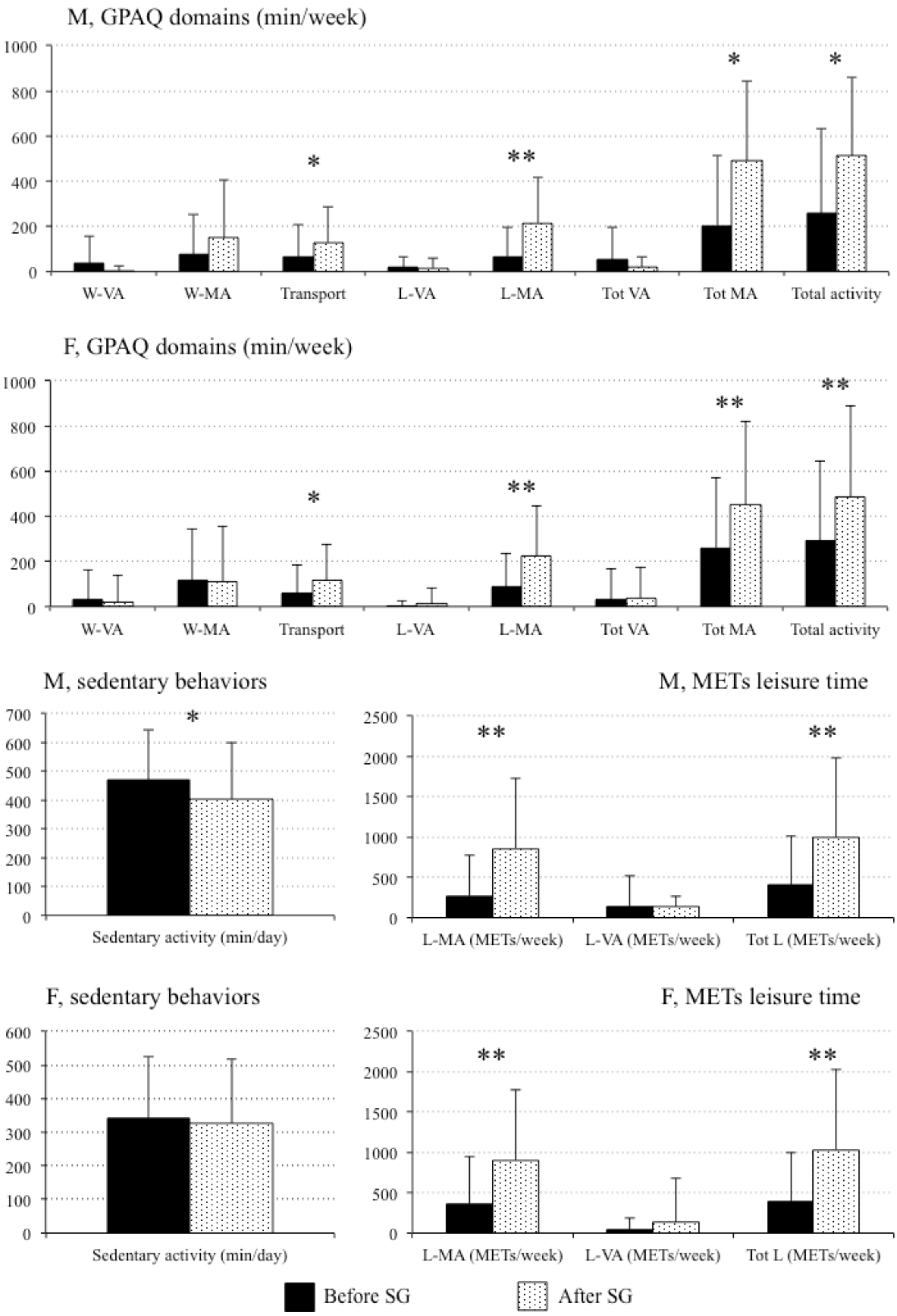
After SG there was not modification in working time spent in moderate or vigorous activity, as well vigorous activity in leisure time. In males and females, moderate activity in leisure time increased significantly (+136.9 min/week in males, +148 min/week in females), as well time spent in transport (+67.3 min/week in males, +55.5 min/week in females). Moreover, both groups reduced the daily minutes dedicated to sedentary behaviors, but this reduction was significant only in males (-67.1 min/day) (Fig. 7).

Tab. 13: physical activity before and after SG

		Males (m±sd)	Males (Δ)	Females (m±sd)	Females (Δ)
W-VA (m/w)	Pre Post	36.9±121.8 4.6±21.2	-32.3 m/w	28.6±132.6 22.1±115.1	-6.5 m/w
W-MA (m/w)	Pre Post	74.6±179.2 149.6±255.3	+75 m/w	114.9±229.2 109.1±243.3	-5.8 m/w
Transport (m/w)	Pre Post	62.4±146.4 130.0±159.4*	+67.3 m/w	59.3±126.5 114.8±162.9**	+55.5 m/w
L-VA (m/w)	Pre Post	17.1±47.3 16.3±40.7	-0.9 m/w	4.4±19.4 16.2±68.2	+11.8 m/w
L-MA (m/w)	Pre Post	66.9±127.5 214.9±204.7**	+148 m/w	89.0±148.1 225.9±217.0**	+136.9 m/w
Tot VA (m/w)	Pre Post	54.0±142.2 20.9±44.2	-33.1 m/w	33.0±133.0 38.3±135.7	+5.3 m/w
Tot MA (m/w)	Pre Post	204.1±308.6 490.1±352.1*	+286 m/w	261.0±309.1 448.8±373.3**	+187.8 m/w
Tot activity (m/w)	Pre Post	258.1±372.6 511.0±350.4*	+252.9 m/w	294.0±350.5 487.1±402.9**	+193.2 m/w
Tot METs (METs/week)	Pre Post	1248.6±1888.5 2127.4±1417.3*	+878.9 METs/week	1307.7±1723.2 2101.7±1885.5**	+794 METs/week
Sedentary activity (min/day)	Pre Post	468.9±175.5 401.7±199.6*	-67.1 m/w	340.0±186.5 326.1±193.1	-13.9 m/w
L-MA (METs/week)	Pre Post	267.4±510.0 859.4±818.7**	+592 METs/week	355.8±592.4 903.6±867.8**	+547.7 METs/week
L-VA (METs/week)	Pre Post	137.1±378.5 130.3±325.9	-6.9 METs/week	35.1±155.3 129.8±545.3	+94.7 METs/week
Tot L-METs (METs/week)	Pre Post	404.6±601.5 989.7±783.4**	+585.1 METs/week	390.9±605.0 1033.4±987.9**	+642.5 METs/week

Abbreviation: m/w: min/week; W-VA: vigorous activity at work; W-MA: moderate activity at work; Tot: total; L-VA: vigorous activity in leisure time; L-MA: moderate activity in leisure time; METs: metabolic equivalent of task; m±sd: mean ± standard deviation; Δ: change from post to pre; * $p<0.05$; ** $p<0.001$

Fig. 7: physical activity before and after SG



Abbreviation: W-VA: vigorous activity at work; W-MA: moderate activity at work; L-VA: vigorous activity in leisure time; L-MA: moderate activity in leisure time; Tot: total; METs: metabolic equivalent of task; M: male; F: female; SG: sleeve gastrectomy; * $p<0.05$; ** $p<0.001$

3.1.5. Quality of life

Quality of life was evaluated with the Short-form Health Survey (SF-36) (Tab. 14).

Tab. 14: quality of life before and after SG

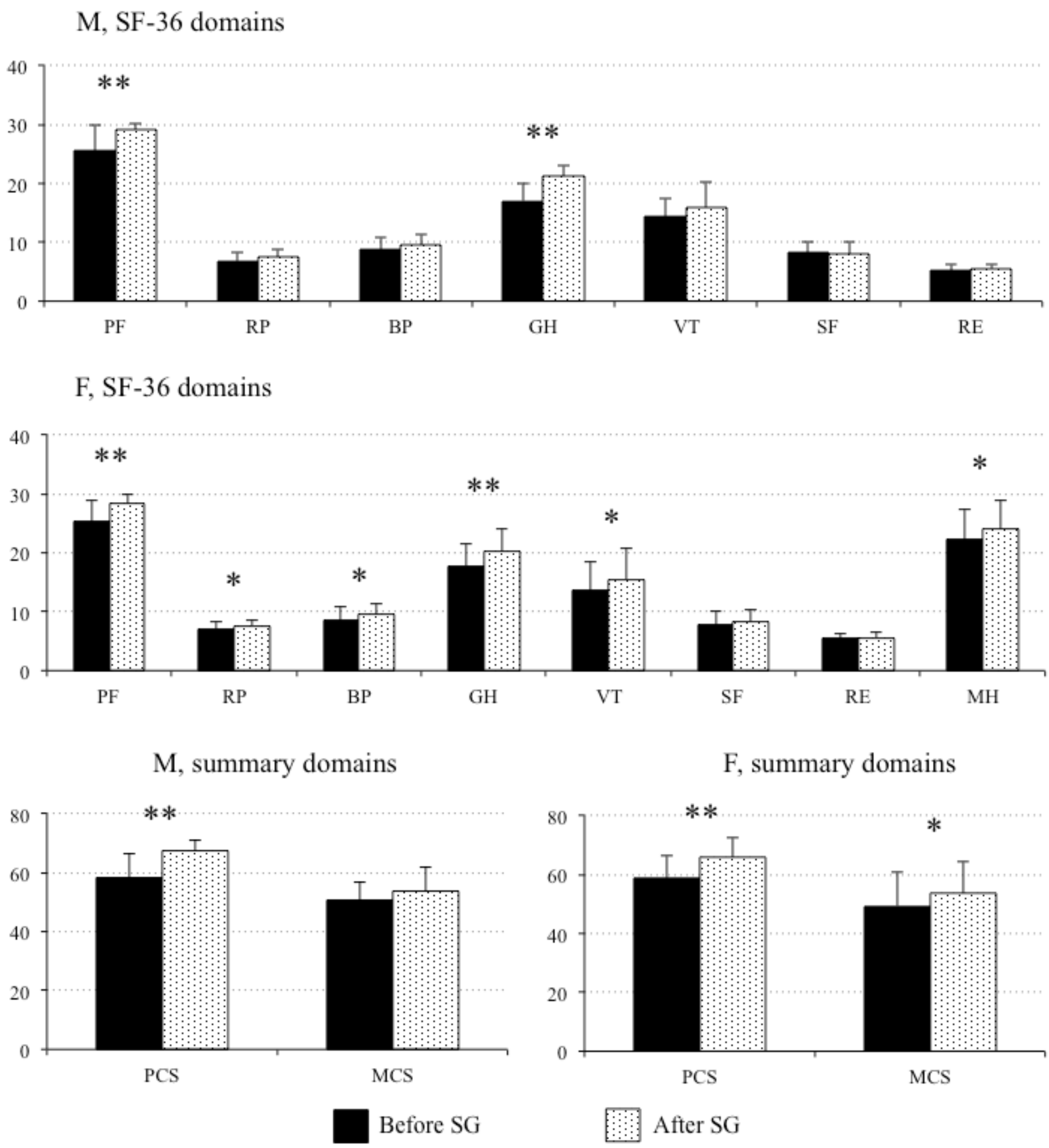
		Males (m±sd)	Males (Δ)	Females (m±sd)	Females (Δ)
PF	Pre	25.5±4.3	+3.6	25.3±3.6	+3.1
	Post	29.1±1.0**		28.3±1.6**	
RP	Pre	6.8±1.5	+0.6	7.1±1.3	+0.6
	Post	7.5±1.2		7.7±0.9*	
BP	Pre	8.8±2.0	+0.7	8.5±2.4	+0.9
	Post	9.5±1.8		9.5±2.0*	
GH	Pre	17.0±3.0	+4.2	17.8±3.7	+2.5
	Post	21.2±1.9**		20.3±3.9**	
VT	Pre	14.4±3.1	+1.5	13.6±4.7	+1.9
	Post	15.9±4.3		15.5±5.1*	
SF	Pre	8.2±1.9	-0.2	7.7±2.4	+0.6
	Post	8.0±2.2		8.4±2.0	
RE	Pre	5.2±1.0	+0.3	5.4±1.0	+0.2
	Post	5.5±0.7		5.6±0.8	
MH	Pre	23.1±4.1	+1.2	22.3±5.2	+1.8
	Post	24.3±3.9		24.1±4.9*	
PCS	Pre	58.2±8.2	+9.1	58.6±7.7	+7.1
	Post	67.3±3.7**		65.7±7.0**	
MCS	Pre	50.9±5.8	+2.8	49.4±11.3	+4.2
	Post	53.7±8.1		53.5±10.7*	

Abbreviation: PF: physical functioning; RP: physical role functioning; BP: bodily pain; GH: general health; VT: vitality; SF: social role functioning; RE: emotional role functioning; MH: mental health; PCS: physical composite score; MCS: mental composite score; m±sd: mean ± standard deviation; Δ: change from post to pre; * $p<0.05$; ** $p<0.001$

Quality of life after SG showed improvement of all parameters, except for *emotional role functioning* in male group (-0.2). The four physical domains improved significantly on female group, while males recorded significant improvement only in *physical functioning* (+3.6) and *general health* (+4.2) domain. The general physical domain improved significantly in both groups (+9.1 in males, +7.1 in females).

After SG, the four mental domains did not improved significantly in male group, while *social role functioning* decreased (-0.2). In females, all the four parameters had a positive trend, but only *vitality* (+1.9) and *mental health* (+1.8) reached the statistical significance. General mental domain increased significantly in female group (+4.2) (Fig. 8).

Fig. 8: quality of life before and after SG



Abbreviation: PF: physical functioning; RP: physical role functioning; BP: bodily pain; GH: general health; VT: vitality; SF: social role functioning; RE: emotional role functioning; MH: mental health; PCS: physical composite score; MCS: mental composite score; M: male; F: female; SG: sleeve gastrectomy; * p<0.05; ** p<0.001

3.3 Physical exercise intervention after bariatric surgery

Twenty-eight persons were recruited for physical exercise intervention after bariatric surgery. Three subjects (1 male and 2 females) dropped out due to work-injury, change work, and personal reasons. Twenty-five persons completed the entire program, without adverse effects (Tab. 15).

Tab. 15: baseline characteristics of physical exercise protocol participants

Gender (M; F)	4 males; 21 females
Age (years)	47.5±8.4
Weight (kg)	88.9±17.3
Height (m)	1.7±0.1
BMI (kg/m^2)	32.1±5.3
Comorbidities (num)	IPTS (6), DMT2 (2), hypothyroidism (5), heart disease (8), asthma (2), OSAS (3), anemia (3), depression (2)

Abbreviation: M: male; F: female; BMI: body mass index; IPTS: hypertension; DMT2: type 2 diabetes mellitus; OSAS: obstructive sleep apnea syndrome

Muscular strength of upper and lower limb showed significant improvement. Lower limb strength evaluated with 30CST demonstrated a significant improvement of 22.9%; moreover, upper limb strength evaluated with 30ACT showed significant improvement of 16.4% and 18.8% for the right and left arm respectively. All patients improved their dynamic balance and agility capacity recording a reduction in execution time of 13.2%. Lower body flexibility evaluate with SRT recorded significant improvement only for the right side (118.7%), while the left side improved but not in significant manner (129.9%). The BS showed significant improvement in right (51.5%) and left (30.1%) shoulder flexibility (Tab. 16).

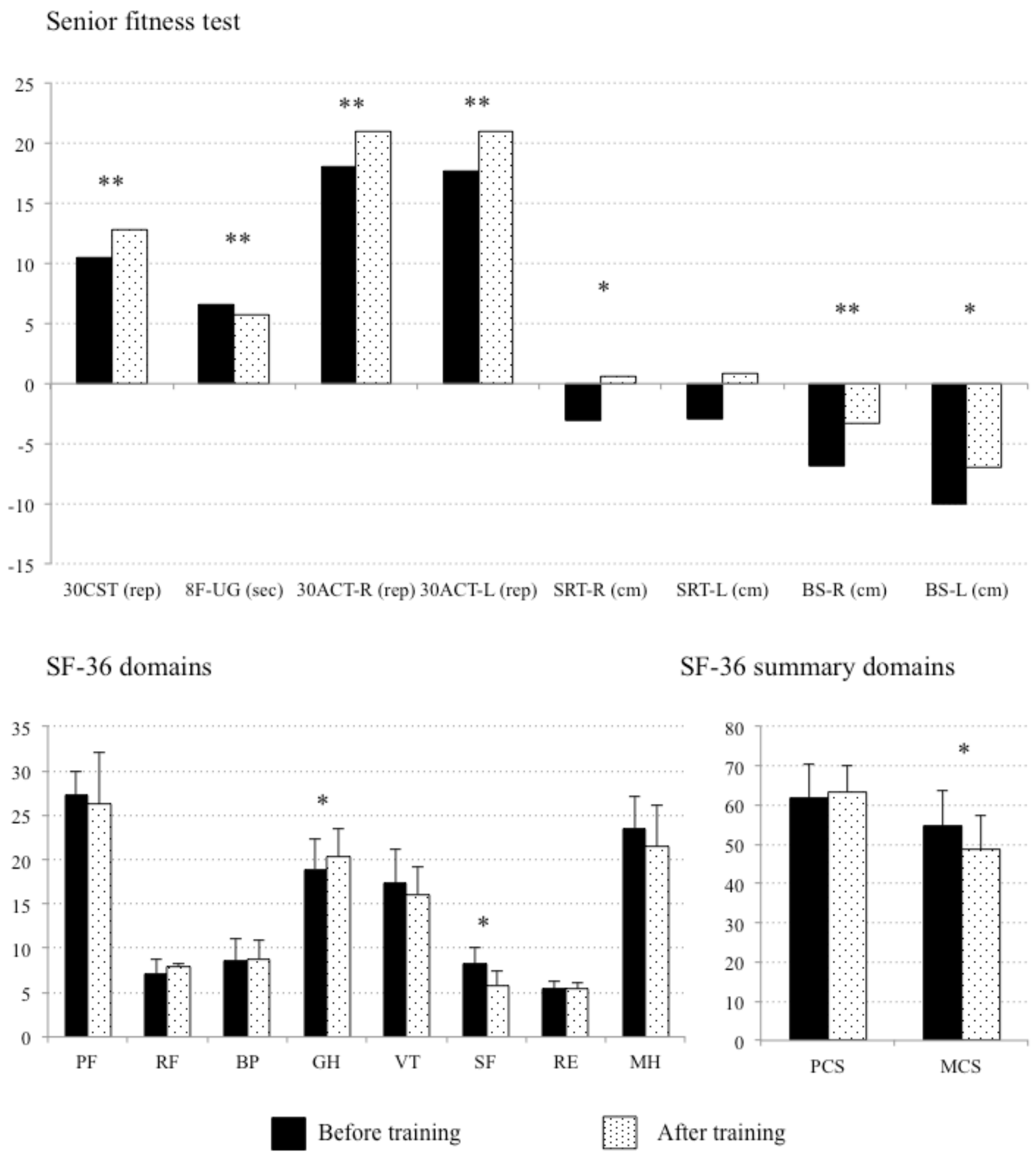
Quality of life assessment before and after physical exercise intervention revealed different tendency. *Physical functioning* decreased after 10 exercise sessions (-3.5%), while *physical role functioning*, *bodily pain*, and *general health* showed an improvement of 10.6%, 3.3%, and 7.6% respectively. Only *general health* improvement was statistically significant. On the contrary, all parameters of mental health worsened (*vitality* -7%, *social role functioning* -29.3%, *emotional role functioning* -1.8%, *mental health* -8.9%), but only *social role functioning* was statistically significant. Physical component score increased by 2.5% but was not statistically significant, while mental component score detected a significant worsening (-10.7%) (Fig. 9).

Tab. 16: pre- to -post-intervention functional evaluation and quality of life assessment (mean ± standard deviation)

Tests	Pre	Post	Improved-Unchanged-Worsened
30CST (rep)	10.5±3.7	12.9±3.6**	22-3-0
8F-UG (sec)	6.6±1.3	5.7±1.0**	25-0-0
30ACT-R (rep)	18.1±3.4	21.0±3.8**	21-2-2
30ACT-L (rep)	17.7±3.6	21.0±3.4**	20-5-0
SRT-R (cm)	-3.0±11.1	0.6±14.7*	17-2-6
SRT-SL(cm)	-3.0±12.3	0.9±13.6	13-4-8
BS-R (cm)	-6.8±10.7	-3.3±9.7**	20-3-2
BS-L (cm)	-10.0±11.8	-7.0±10.0*	18-2-5
PF	27.2±2.6	26.3±5.8	
RF	7.2±1.5	7.9±0.3	
BP	8.5±2.5	8.8±2.0	
GH	18.9±3.4	20.4±3.1*	
VT	17.3±3.9	16.1±3.1	
SF	8.2±1.8	5.8±1.7*	
RE	5.5±0.9	5.4±0.8	
MH	23.5±3.6	21.5±4.7	
PCS	61.8±8.7	63.4±6.5	
MCS	54.5±9.1	48.7±8.5*	

Abbreviation: 30CST: 30-second chair stand test; 8F-UG: 8-foot up-and-go test; 30ACT: 30-second arm curl test; SRT: sit-and-reach test; BS: back scratch test; R: right; L: left; rep: repetitions; sec: seconds; cm: centimeters; PF: physical functioning; RP: physical role functioning; BP: bodily pain; GH: general health; VT: vitality; SF: social role functioning; RE: emotional role functioning; MH: mental health; PCS: physical composite score; MCS: mental composite score; m±sd: mean ± standard deviation; * p<0.05; ** p<0.001

Fig. 9: senior fitness test and quality of life before and after physical exercise program



Abbreviation: 30CST: 30-second chair stand test; 8F-UG: 8-foot up-and-go test; 30ACT: 30-second arm curl test; SRT: sit-and-reach test; BS: back scratch test; R: right; L: left; rep: repetitions; sec: seconds; cm: centimeters; PF: physical functioning; RP: physical role functioning; BP: bodily pain; GH: general health; VT: vitality; SF: social role functioning; RE: emotional role functioning; MH: mental health; PCS: physical composite score; MCS: mental composite score; * $p<0.05$; ** $p<0.001$

4. DISCUSSION

The aim of this study was to analyze the modification of physical functioning in patients with obesity undergoing sleeve gastrectomy. The main results showed a significant reduction of body weight, BMI, and waist circumference. Moreover, 85.7% of males and 76.9% of females lost more than 50% of Excess BMI. After SG, muscular strength and absolute maximal oxygen consumption tended to decrease, while these same parameters, corrected by body weight, tended to increase.
Physical exercise protocol induced a significant improvement of muscular strength, dynamic balance and flexibility, without showing any adverse effects.

4.1 The influence of anthropometrics and functional parameters in weight loss

The main mechanisms involved in weight loss are the balance between energy intake and energy expenditure. The role of bariatric surgery is to reduce the energy intake and induce a negative balance in favor of energy deficit to facilitate weight loss. Despite this, several factors could influence weight loss. A recent study examined predictive parameters for weight loss after bariatric surgery. Results showed a significant higher %-EX-BMI-L in patients younger than 50 years old [24]. In our study age, the mean age of patients who reached 50% of BMI loss was 48 y.o, while who reached the goal was 44 y.o. Moreover, pre-surgery age is negative correlated with body weight loss and percentage of excess BMI loss.
The evaluation of muscular strength, i.e. handgrip test, is commonly diffused in clinical practice [25]. In fact, low handgrip strength is associated with sarcopenia, functional impairment, and disabilities [26]. Moreover, adults with higher level of muscle strength, evaluated with handgrip test, showed a reduction of 31% of all-causes-mortality [26]. Very few studies examined pre-operative muscular strength evaluated with handgrip test in relation to weight loss and change of body composition [27]. The authors found a significant relationship between pre-operative handgrip test, body composition and BMI, 18 weeks after bariatric surgery [27]. These results are partially confirmed in our study. In fact, we found a small correlation between pre-surgery dominant and non-dominant handgrip test and body weight loss (kg, %) in females. Moreover, also isometric muscular strength of knee extensors showed a moderate correlation with weight loss, and a weak correlation with %Ex-BMI-L. However, in males, muscular strength seems not to be correlated with weight loss. Probably, body composition assessment is necessary to better understand the real role of muscle strength and muscle mass on weight loss.

4.2 Functional capacity modification after sleeve gastrectomy

Bariatric surgery and the related weight loss are associated with an increase in exercise tolerance [28], relative muscle mass [15] and modification in lifestyle and quality of life [29].

4.2.1 Muscular strength modification after sleeve gastrectomy

In healthy adults, isometric and isokinetic absolute muscular strength are negatively correlated with age, while a positive correlation with height and body weight is demonstrated [30]. In obese subjects, several studies demonstrated higher absolute maximal voluntary contraction (MVC) torque compared with normal weight subjects; on the contrary MVC adjusted for body weight and fat-free mass appear reduced in obese subjects [31, 32]. After bariatric surgery, functional capacity in obese patients changes, due to different mechanism induced by weight loss. In fact, weight loss consists mainly of fat mass, but also muscle mass. According to several studies [15, 33], absolute muscle strength of upper and lower limb decreased after SG. On the contrary, relative muscle strength increased significantly 6 months after surgery [33]. Since that muscle strength is correlated with body weight only in female group, and no correlation was found between weight loss and change in absolute muscle strength, we can speculate that muscle mass is able to influence the absolute strength after SG. Unfortunately, we haven't the body composition of our patients, and it is unclear the real tendency of muscle strength and muscle mass after bariatric surgery.

4.2.2 Maximal oxygen consumption modification after sleeve gastrectomy

Maximal oxygen consumption is an important measure of cardiorespiratory capacity, and a lower capacity is correlated with higher risk for cardiovascular mortality [34]. In healthy adults, fat mass has a strong negative correlation with VO_2max, while fat free mass presents a moderate positive correlation [35]. This relationship could explain the correlation between pre-surgery muscular strength and maximal oxygen consumption. Despite this, change in muscle strength is not correlated with change of VO_{2max}, suggesting different mechanisms influencing the observed changes of cardiopulmonary and muscular capacity after bariatric surgery.

4.2.3 Static balance modification after sleeve gastrectomy

Increased body weight is associated with an increased risk of falls in different population, including obese individuals [15]. Indeed, greater muscle strength is necessary to control static balance in people with large postural sway [36]. In our findings, lower limb isometric strength of male subjects had a positive correlation with static balance. This result is in agreement with the above-mentioned study, and higher strength capacity are necessary for balance control [15]. On the contrary, static balance is negatively correlated with females' body weight, without correlation between lower limb muscle strength and static balance. Several studies found improvement of static balance after weight loss. Moreover, seems that in males the improvement was detected by weight loss, more than maintaining muscle strength [15, 37]. Our analysis is in contrast with the above-mentioned study; in fact, the maintenance of lower limb strength is correlated with static balance improvement in both sexes. On the contrary, weight loss in males is correlated with a worsening of static balance. Considering that a higher muscle strength is necessary for balance control in obese subjects, the potential loss of muscle mass observed after bariatric surgery, could have affected balance control, especially in patients that lost more percentage of initial weight.

4.3 The role of exercise before and after bariatric surgery

Physical activity is strongly recommended before and after bariatric surgery. The American Society for Metabolic and Bariatric Surgery (ASMBS) recommends 20 daily minutes of mild aerobic and strength exercises 3 times per week to improve cardiorespiratory fitness and reduce the risk of surgical complications [12]. The relationship between pre-surgery, post-surgery, and change in physical activity after bariatric surgery is not so clear. Studies that analyzed pre-operative physical activity found that lower level of physical activity is associated with lower body weight loss. Comparable results were found for post- surgical physical activity, with higher weight loss observed in more active patients [16]. Despite this, the real effect of physical activity is still unclear, and longitudinal studies found heterogeneous results. Probably, self-reported questionnaire is not the better way to quantify physical activity in patients with obesity, and an objective assessment throughout accelerometers is needed [16].

The increase of spontaneous physical activity after bariatric surgery is currently demonstrated; however, a recent work found that only 11% of patients reached the recommended minimal level of physical activity (at least 150 minute of moderate activity, or 75 minute of vigorous activity) [38], and 24-29% of patients reported a decrease [39]. The hypothesis to explain the low adherence to exercise could be related to the real influence of exercise for weight loss. Exercise alone induces low weight loss and better results include a diet control. On the contrary, bariatric surgery is the best practice for a greater weight loss. This phenomenon is often perceived as a lack of benefit of exercise in obese patients in absence of detectable weight loss. On the other hand, physiological and psychological benefits are largely demonstrated [38]. On the contrary, physical activity should be promoted before and after bariatric surgery to enable a change in lifestyle, and long-term efficacy of surgery. In fact, preoperative attitude to physical activity (people perceiving more exercise benefits, have more confidence with exercise) and behaviors (increase before surgery) predict higher postoperative physical activity [40].

A systematic review by Chaston and colleagues quantify a loss of fat free mass of about 31% of weight loss induced by bariatric surgery [41]. Moreover, fat free mass loss is associated with a reduction of resting metabolic rate that increase the possibility of weight regain [13]. Physical activity, and mainly resistance training, is able to counteract this phenomenon increasing functional capacity. Twelve weeks of aerobic training, such as combined aerobic and strength training, improved functional capacity in bariatric patients after surgery. Moreover, even if fat free mass decreased in both groups of patients, those who performed strength training lost less FFM than control and aerobic training [42].

Our results confirm the efficacy of a supervised exercise already after 10 sessions, with improvement in lower and upper limb strength, dynamic balance, upper limb articular mobility, and lower limb flexibility.

4.4 Exercise prescription in patients with obesity: some hypothesis

Current guidelines for exercise prescription in patients with obese, recommended at least 150 of weekly minutes of moderate physical activity for a modest weight loss (2-3 kg), while more than 225 weekly minutes are necessary for increased weight loss and prevent weight regain [43]. Guidelines for exercise prescription in patients after bariatric surgery follow the general indication for weight loss and maintenance (Tab. 17) [39]. Nonetheless, there is necessity of developing specific guidelines for patients that undergo bariatric surgery, due to weight loss and functional capacity modification.

Tab. 17: FITT recommendations for individuals with overweight and obesity

	Aerobic	**Resistance**	**Flexibility**
Frequency	≥ 5 days/week	2-3 days/week	≥ 2-3 days/week
Intensity	Initial intensity should be moderate (40%-59% VO_{2res} or HRR); progress to vigorous (≥60% VO_{2res} or HRR) for greater benefits.	60%-70% of 1-RM; gradually increase to enhance strength and muscle mass.	Stretch to the point of felling tightness or slight discomfort.
Time	30 min/day (150 min/week); increased to 60 min/day or more (250-300 min/week).	2-4 sets of 8-12 repetitions for each of the major muscle groups	Hold static stretch for 10-30 seconds; 2-4 repetitions of each exercises
Type	Prolonged, rhythmic activities using large muscle groups (e.g. walking, cycling, swimming)	Resistance machines and/or free weights	Static, dynamic, and/or PNF

Abbreviation: VO_{2res}: oxygen uptake reserve; HRR: heart rate reserve; PNF: proprioceptive neuromuscular facilitation

Starting from results and findings of this investigation, we can hypothesize some integration for specific exercise prescription in patients who underwent bariatric surgery:

- weight loss is negatively correlated with pre-surgery age, muscular strength and VO_{2max}: physical activity could be recommended especially in elderly patients with lower functional capacity before surgery;
- change of lower limb muscular strength is correlated with change of static balance: specific balance training and resistance training of lower limb muscle could be recommended in patients that lost muscular strength, to avoid an increase of falling-risk;
- percentage of excess BMI loss is negatively correlated with static balance: specific balance training could be recommended in patients with higher percentage of excess BMI loss.

4.5 Limitations

This thesis has several limitations. Firstly, body composition analysis was not performed due to a limitation of weight support of dual-energy x-ray absorptiometry. Results in terms of muscle strength changes and effect of fat free mass on weight loss cannot be explained with available data. Secondly, physical activity was not recorded using an objective measures, thus results about physical activity influence on physical performance and weight loss appear uncertain. Finally, we don’t have a detailed dietetic record, to pinpoint the effect of the negative energy intake on the overall and partitioned weight loss [44].

5. CONCLUSION

This study analyzed the effects of sleeve gastrectomy on functional capacity in patients with obesity. After SG, patients with obesity improved their functional capacity, increased time dedicated to physical activity, and improved quality of life. Weight loss resulted negatively correlated with age, while higher pre-surgery muscular strength and maximal oxygen consumption seem to favor weight loss. Moreover, static balance in man worsen in relation to isometric muscle strength decrease. Specific recommendation in exercise prescription should take in account the changes of functional capacity, especially when this functional capacity is not evaluated.

Improvement of upper and lower limb muscular strength, dynamic balance, upper limb articular mobility and lower limb flexibility, was found already after 10 sessions of supervised physical exercise.

Future researches are necessary to integrate these results with data of body composition, objective evaluation of physical activity level, and other long-term clinical outcomes.

References

1. Janmohammadi, P., et al., *Comparison of Energy and Food Intake Between Gastric Bypass and Sleeve Gastrectomy: a Meta-analysis and Systematic Review.* Obes Surg, 2019. **29**(3): p. 1040-1048.
2. WHO. *Obesity and overweight*. 2018 16 February 2018 [cited 2019 20 Sept.]; Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
3. Hruby, A. and F.B. Hu, *The Epidemiology of Obesity: A Big Picture.* Pharmacoeconomics, 2015. **33**(7): p. 673-89.
4. WHO. *Obesity: situation and trends*. 2018 6 May 2019; Available from: https://www.who.int/gho/ncd/risk_factors/physical_activity/en/ (Access on 6 May 2019).
5. Abdelaal, M., C.W. le Roux, and N.G. Docherty, *Morbidity and mortality associated with obesity.* Ann Transl Med, 2017. **5**(7): p. 161.
6. Gray, D.S. and K. Fujioka, *Use of relative weight and Body Mass Index for the determination of adiposity.* J Clin Epidemiol, 1991. **44**(6): p. 545-50.
7. Flint, A.J., et al., *Body mass index, waist circumference, and risk of coronary heart disease: A prospective study among men and women.* Obes Res Clin Pract, 2010. **4**(3): p. e163-246.
8. Gloy, V.L., et al., *Bariatric surgery versus non-surgical treatment for obesity: a systematic review and meta-analysis of randomised controlled trials.* BMJ, 2013. **347**: p. f5934.
9. Noria, S.F. and T. Grantcharov, *Biological effects of bariatric surgery on obesity-related comorbidities.* Can J Surg, 2013. **56**(1): p. 47-57.
10. Cremieux, P.Y., et al., *The impact of bariatric surgery on comorbidities and medication use among obese patients.* Obes Surg, 2010. **20**(7): p. 861-70.
11. Cardoso, L., et al., *Short- and long-term mortality after bariatric surgery: A systematic review and meta-analysis.* Diabetes Obes Metab, 2017. **19**(9): p. 1223-1232.
12. King, W.C. and D.S. Bond, *The importance of preoperative and postoperative physical activity counseling in bariatric surgery.* Exerc Sport Sci Rev, 2013. **41**(1): p. 26-35.
13. Coen, P.M. and B.H. Goodpaster, *A role for exercise after bariatric surgery?* Diabetes Obes Metab, 2016. **18**(1): p. 16-23.
14. Hue, O., et al., *Muscle force and force control after weight loss in obese and morbidly obese men.* Obes Surg, 2008. **18**(9): p. 1112-8.
15. Handrigan, G., et al., *Weight loss and muscular strength affect static balance control.* Int J Obes (Lond), 2010. **34**(5): p. 936-42.

16. Jacobi, D., et al., *Physical activity and weight loss following bariatric surgery.* Obes Rev, 2011. **12**(5): p. 366-77.

17. Faria, S.L., E. Kelly, and O.P. Faria, *Energy expenditure and weight regain in patients submitted to Roux-en-Y gastric bypass.* Obes Surg, 2009. **19**(7): p. 856-9.

18. Tombaugh, T.N. and N.J. McIntyre, *The mini-mental state examination: a comprehensive review.* J Am Geriatr Soc, 1992. **40**(9): p. 922-35.

19. Mathiowetz, V., et al., *Grip and pinch strength: normative data for adults.* Arch Phys Med Rehabil, 1985. **66**(2): p. 69-74.

20. Bergamin, M., et al., *Reliability of a device for the knee and ankle isometric and isokinetic strength testing in older adults.* Muscles Ligaments Tendons J, 2017. **7**(2): p. 323-330.

21. Gobbo, S., et al., *Reliability of an isometric and isokinetic strength testing protocol of the knee and ankle in young adults.* Muscles Ligaments Tendons J, 2019. **9**(3): p. 348-355.

22. Organization, W.H. *Global Physical Activity Questionnaire (GPAQ): Analysis Guide*. Available from: https://www.who.int/ncds/surveillance/steps/resources/GPAQ_Analysis_Guide.pdf.

23. Rikli, R.E. and C.J. Jones, *Development and validation of a functional fitness test for community-residing older adults.* Journal of Aging and Physical Activity, 1999. **7**(2): p. 129-161.

24. Huang, C.W., et al., *Predicted weight loss result of laparoscopic sleeve gastrectomy: Review of the first 82 consecutive patients in an Asian bariatric unit.* Asian J Surg, 2019. **42**(1): p. 373-378.

25. Montano-Loza, A.J., et al., *Muscle wasting is associated with mortality in patients with cirrhosis.* Clin Gastroenterol Hepatol, 2012. **10**(2): p. 166-73, 173 e1.

26. Garcia-Hermoso, A., et al., *Muscular Strength as a Predictor of All-Cause Mortality in an Apparently Healthy Population: A Systematic Review and Meta-Analysis of Data From Approximately 2 Million Men and Women.* Arch Phys Med Rehabil, 2018. **99**(10): p. 2100-2113 e5.

27. Otto, M., et al., *Handgrip strength as a predictor for post bariatric body composition.* Obes Surg, 2014. **24**(12): p. 2082-8.

28. Neunhaeuserer, D., et al., *Functional Evaluation in Obese Patients Before and After Sleeve Gastrectomy.* Obes Surg, 2017. **27**(12): p. 3230-3239.

29. Versteegden, D.P.A., M.J.J. Van Himbeeck, and S.W. Nienhuijs, *Improvement in quality of life after bariatric surgery: sleeve versus bypass.* Surg Obes Relat Dis, 2018. **14**(2): p. 170-174.

30. Harbo, T., J. Brincks, and H. Andersen, *Maximal isokinetic and isometric muscle strength of major muscle groups related to age, body mass, height, and sex in 178 healthy subjects.* Eur J Appl Physiol, 2012. **112**(1): p. 267-75.

31. Hulens, M., et al., *Study of differences in peripheral muscle strength of lean versus obese women: an allometric approach.* Int J Obes Relat Metab Disord, 2001. **25**(5): p. 676-81.
32. Gadducci, A.V., et al., *Muscle strength and body composition in severe obesity.* Clinics (Sao Paulo), 2017. **72**(5): p. 272-275.
33. Alba, D.L., et al., *Changes in Lean Mass, Absolute and Relative Muscle Strength, and Physical Performance After Gastric Bypass Surgery.* J Clin Endocrinol Metab, 2019. **104**(3): p. 711-720.
34. Lee, D.C., et al., *Mortality trends in the general population: the importance of cardiorespiratory fitness.* J Psychopharmacol, 2010. **24**(4 Suppl): p. 27-35.
35. Mondal, H. and S.P. Mishra, *Effect of BMI, Body Fat Percentage and Fat Free Mass on Maximal Oxygen Consumption in Healthy Young Adults.* J Clin Diagn Res, 2017. **11**(6): p. CC17-CC20.
36. Corbeil, P., et al., *Increased risk for falling associated with obesity: mathematical modeling of postural control.* IEEE Trans Neural Syst Rehabil Eng, 2001. **9**(2): p. 126-36.
37. Teasdale, N., et al., *Reducing weight increases postural stability in obese and morbid obese men.* Int J Obes (Lond), 2007. **31**(1): p. 153-60.
38. Coen, P.M., E.A. Carnero, and B.H. Goodpaster, *Exercise and Bariatric Surgery: An Effective Therapeutic Strategy.* Exerc Sport Sci Rev, 2018. **46**(4): p. 262-270.
39. American College of Sports, M., et al., *ACSM's guidelines for exercise testing and prescription*. 2018.
40. Mitchell, J.E. and M. De Zwaan, *Psychosocial Assessment and Treatment of Bariatric Surgery Patients*. 2011: Routledge.
41. Chaston, T.B., J.B. Dixon, and P.E. O'Brien, *Changes in fat-free mass during significant weight loss: a systematic review.* Int J Obes (Lond), 2007. **31**(5): p. 743-50.
42. Hassannejad, A., et al., *The Effect of Aerobic or Aerobic-Strength Exercise on Body Composition and Functional Capacity in Patients with BMI >/=35 after Bariatric Surgery: a Randomized Control Trial.* Obes Surg, 2017. **27**(11): p. 2792-2801.
43. Donnelly, J.E., et al., *American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults.* Med Sci Sports Exerc, 2009. **41**(2): p. 459-71.
44. Foster-Schubert, K.E., et al., *Effect of diet and exercise, alone or combined, on weight and body composition in overweight-to-obese postmenopausal women.* Obesity (Silver Spring), 2012. **20**(8): p. 1628-38.

ABBREVIATION

WHO: World Health Organization

FFM: fat free mass

SG: sleeve gastrectomy

DMT2: type 2 diabetes mellitus

IPTS: hypertension

OSAS: obstructive sleep apnea syndrome

MMSE: mini mental state examination

M: male

F: female

Anthropometrics and cardiopulmonary parameters

BMI: Body Mass Index

%-Ex-BMI-L: percentage of excess body mass index loss

WC: Waist circumference

CPET: cardiopulmonary exercise test

VO_{2max}: maximal oxygen consumption

Muscular strength parameters

HG: handgrip test

Fmax: maximal muscular strength

Fmean: mean muscular strength

Ext: extension

Flex: flexion

Static balance parameters

CoP: center of pressure

SP: sway path

SA: sway area

APO: antero-posterior oscillation

MLO: medio-lateral oscillation

EO: eyes opened

EC: eyes closed

Physical functioning evaluation

30CST: 30-second chair stand test

30-ACT: 30-second arm curl test

8-F-UG: 8-foot up-and-go

SRT: chair sit-and-reach test

BS: back scratch test

R: right

L: left

Questionnaires parameters

GPAQ: global physical activity questionnaire

W-VA: vigorous activity at work

W-MA: moderate activity at work

L-VA: vigorous activity in leisure time

L-MA: moderate activity in leisure time

METs: metabolic equivalent of task

SF-36: Short Form Health Survey 36-item

PF: physical functioning

RP: physical role functioning

BP: bodily pain

GH: general health

VT: vitality

SF: social role functioning

RE: emotional role functioning

MH: mental health

PCS: physical health summary

MCS: mental health summary