Research Article

Effects of an Intensive Inpatient Rehabilitation Program in Elderly Patients with Obesity

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Abstract

Objective: The aim of this study was to assess the short-term effectiveness of an intensive inpatient multidimensional rehabilitation program (MRP), including diet, exercise, and behavioral therapy, in elderly patients with severe obesity. ***Methods:*** Forty-four elderly patients (old; age 69.3 ± 3.5 years, BMI 41.9 ± 14.9) were analyzed against 215 younger patients (young; age 48.2 ± 18.5 years, BMI 43.9 ± 9.4), who were used as controls. All patients underwent MRP, based on group therapy guided by a multidisciplinary team (physicians, dietitians, exercise trainers, psychologists). We evaluated changes in anthropometry, cardiovascular risk factors, physical fitness, quality of life, and eating behavior. ***Results:*** After 3 weeks of MRP, we observed a reduction in body weight (old –3.8%, young –4.3%), BMI (old –3.9%, young –4.4%), waist circumference (old –3.4%, young –4.1%), total cholesterol (old –14.0%, young –15.0%), and fasting glucose (old –8.3%, young –8.1%), as well as improved performance in the Six-Minute-Walk Test (old +28.7%, young +15.3%), chair-stand test (old +24.8%, young +26.9%), and arm-curl test (old +15.2%, young +27.3%). Significant improvement was registered in all other analyzed domains. ***Conclusion:*** Our 3-week MRP provided significant clinical and functional improvement, which was similar between elderly and younger patients with severe obesity. In the long-term, this may be translated into better quality of life, through better management of obesity-associated morbidities and reduced frailty.

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Introduction

The prevalence of obesity has dramatically increased worldwide over the past decades, and this led the World Health Organization to declare a global obesity epidemic, considering the negative impact that obesity has on public health [1]. Furthermore, obesity is associated with greater risk of developing several chronic diseases including cardiovascular disease, diabetes mellitus, cancer, and osteoarthritis [2] with consequent increased risk of disability [3, 4].

At the same time, a steady increase in life expectancy has been reported, with projection indicating that the European population over 65 years will reach 30% by 2060 [5]. As individuals live longer, chronic health concerns greatly affect their quality of life. Likewise, the prevalence of obesity in the older population is on the rise, thus becoming one of the greatest public health concerns in the elderly, as it is associated with increased cardiometabolic risk, physical disability, impaired quality of life and sexual dysfunctions, lower urinary tract symptoms, as well as decreased cognitive function and dementia [6, 7].

In addition, obesity in the elderly is associated with decreased ability to perform physical activity, which determines a higher risk for frailty. A report of the English Longitudinal Study of Ageing has shown that frailty in community-dwelling men and women (>65 years old) was related to Body Mass Index (BMI) in a U-shape manner; extremely low or high BMI are associated with increased frailty [8]. Furthermore, obesity is associated with accelerated biological ageing process, as indicated by increased shortening of telomere length [9]. Another important aspect associated with ageing is change in body composition, with progressive loss of lean mass (especially muscle mass) and strength, a condition defined as sarcopenic obesity [10]. Hence, adipose accumulation and muscle loss are cyclically reinforcing, so that frailty can be markedly progressive, determining a direct impact on self-care and increased health costs.

Although several studies demonstrate the negative impact of obesity in the elderly, the recommendations for obesity management in this population are still scarce. Nevertheless, lifestyle modification through healthy diet and regular physical activity is considered the standard of care and the first step in obesity management [11, 12], while other therapeutic interventions (pharmacotherapy and bariatric surgery) have been demonstrated to be beneficial. Albeit the number of elderly subjects in these trials is limited, it becomes clear that the primary goal in this population is the reduction of adiposity and preservation of muscle mass and function, in order to prevent frailty [13]. In this direction, nutritional education and physical exercise represent the cornerstone, and can be implemented through programs of personalized or group-based behavioral therapy [11, 12].

The aim of our study was to assess the short-term effects on health and functional capacity of an intense inpatient rehabilitation program, including behavior intervention, diet, regular exercise and lifestyle counselling, in a group of elderly patients with severe obesity as compared to younger ones.

Methods

Patients

A total of 259 adult patients with severe obesity and obesity-related comorbidities consecutively admitted to a multidimensional rehabilitation program (MRP) from 1st January 2016 to 1st April 2017 were included in the present study. Patients with a major orthopedic, neurologic, or psychiatric disease, as well as those with a clinical indication to use a very low-calorie diet (i.e., prior to bariatric, orthopedic or cardiac surgery) were excluded by the study. According to their age, subjects were divided into two groups, young (<65 years old, n = 215) and old (≥65 years old, n = 44). During MRP, patients were followed by a multidisciplinary team and underwent group as well as individualized interventions.

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Description of the Rehabilitation Program

The MRP has been developed and conducted at the "Solatrix" Clinic, Rovereto, Trentino region, Italy, and it has been previously described [14]. Briefly, the admission was consented in accordance with the criteria of appropriateness for inpatient obesity rehabilitation released by the Italian Society for Obesity [15] and the costs were covered by the Italian National Health Service. The MRP was conducted in groups of 12–14 patients. At the beginning and at the end of the MRP, all patients underwent a multidimensional assessment regarding clinical status, cardiovascular risk, eating behavior, quality of life, and physical performance.

Medical Evaluation

At the beginning of the MRP, patients underwent a complete clinical evaluation including medical history, physical examination and assessment of cardiovascular risk factors, in order to identify obesity-related comorbidities and adjust accordingly medical therapy, as previously described [14]. Serum levels of glucose (Glc), glycated hemoglobin (HbA1c), total cholesterol (TC), HDL-cholesterol (HDL), triglycerides (TG), and uric acid were assessed at admission and discharge. Patients were diagnosed with type 2 diabetes if they had fasting Glc ≥126 mg/dL or HbA1c ≥6.5% or if they were under antidiabetic therapy [16]. Hypertension was defined as blood pressure ≥140/90 mm Hg or the use of any antihypertensive drug [17]. Non-alcoholic fatty liver disease was diagnosed by abdominal ultrasound [18]. Obstructive sleep apnea syndrome was diagnosed according to the results of a nocturnal instrumental registration of the breathing pattern during sleep and standardized diagnostic criteria [19]. Osteoarthritis (OA) was defined clinically as the presence of chronic pain in the weight-bearing joints with or without the use of pain-suppressing medications. If necessary, a psychiatric evaluation was made.

Nutritional Assessment and Intervention

Once a week, patients underwent anthropometric evaluation. Body weight (BW) was measured to the nearest 0.1 kg using a regularly calibrated electronic calibrate balance, in light clothes and without shoes. Body height was measured to the nearest 0.5 cm with the subject standing erect and barefooted using a stadiometer with a movable piece levelled with skull vault. BMI was calculated as weight in kilograms divided by height in meters squared. Waist circumference (WC) was measured to the nearest 0.5 cm on a horizontal plane at the midpoint between the lowest rib and the iliac crest, usually corresponding to the level of the umbilicus, at the end of a normal expiration, with the subject standing erect with relaxed abdominal muscles, arms at the side, and feet together [20]. Neck circumference was measured to the nearest 0.5 cm at the mid-neck level, between mid-cervical spine and mid-anterior neck, just below the cricoid cartilage [21]. In addition, patients underwent bioelectric impedance analysis (BIA; BIA 101 Anniversary device, Akern). Indexes of body composition, fat-free mass (kg/m), fat mass (kg/m), total body water (TBW, L/m), were calculated by taking into consideration BIA and anthropometric measurements (BW, body height, sex, and age).

After a baseline nutritional assessment including a 24-h dietary recall and diet history, each patient received a personalized diet plan, prescribed by the dietitian. Diet was designed to elicit a caloric deficit of 800–1,000 kcal/day with respect to the estimated individual daily total energy requirements, calculated according to basal metabolic rate (BMR) estimated with the Harris-Benedict equation, and adjusted for physical activity [22]. Total protein intake was set to 0.8–1 g/kg of ideal BW (calculated as the BW corresponding to a BMI of 22.5–25.0) and approximately 20% of the daily energy intake, with carbohydrates representing 50–55% and fat 25–30% of daily intake [23]. In addition, daily educational meetings were organized in order to provide proper information and skills to enhance lifestyle modification and restore correct eating habits.

Psychological Evaluation and Support

All patients admitted to the obesity rehabilitation program attended once-a-week individual session with an experienced psychologist and two weekly group meetings conducted by the same psychologist (the first one concerning mind-set and emotions involved on patient's eating behaviors; the second one being a motivational group). Psychological approach was based on the cognitive-behavioral therapy of obesity [24] as well as a systemic/strategic approach [25]. Psychological individual sessions initially aimed at a diagnostic assessment and to the listing of weight-related problems [26]. The subsequent aim was to increase patient's awareness concerning emotional eating and their own mind-set (automatic thoughts) concerning eating behaviors [27]. A particular focus was placed on relapse prevention and weight regain. Instruments

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used during psychological individual interviews included food/emotional diary, weight problem formulation, problem solving, mindful eating [28], and other cognitive behavioral techniques. The motivational group focused on the trans-theoretical model and the wheel of change of Prochaska and Di Clemente [29], while the other group focused on increasing patient's awareness about the relation between food and emotions, and on learning cognitive and behavioral ways to identify and to manage internal and external critical situations. A psychologist leads the meeting by using assertive abilities of patients in order to make them recognize their own food-related needs, experiences and desires, and making them aware of their own emotionality.

Health-related quality of life was analyzed with the standard (4-week) recall version 2.0 of the 36-item Health Survey (SF-36) questionnaire form. The SF-36 measures the following eight subscales: physical functioning, social functioning, role limitations due to a physical problem, role limitations due to an emotional problem, mental health, vitality, bodily pain, and general health perception. The eight subscales form two distinct higher-ordered summary scales: the Physical Component Summary Scale (PCS) and the Mental Summary Component Scale (MCS) [30]. Binge eating was tested with the use of the Binge Eating Scale (BES) [31].

Functional Evaluation and Exercise Prescription

A graded cardiopulmonary exercise test (CPET) was performed for the aerobic assessment of patients. CPET was conducted on an electromagnetically braked cycle ergometer (Bike RHC 400; CLE Elettromedicali, San Bellino, Italy). After 1 min of rest at the standing position and 1 min of freewheel at a constant cadence between 55 and 65 rpm, the workload was set at 30 (females or deconditioned males) or 60 W (males) and was increased by 15 W every 2 min until volitional exhaustion. Patients were continuously monitored with a 12-lead electrocardiogram (XScribe5; Mortara Instrument Inc., Milwaukee, WI, USA) and a pulse oximeter (PalmSAT 2500; Nonin Medical Inc., Plymouth, MN, USA), while oxygen consumption (VO_2), carbon dioxide production (VCO_2), and pulmonary ventilation (VE), were measured breath-by-breath through an open-circuit gas analysis system (K5; Cosmed srl, Rome, Italy). Careful calibration of flow sensors and gas analysis system was performed before each test according to manufacturer's instructions. Cardiorespiratory parameters (VO_2, VCO_2, VE, HR) and power output (PO) were determined at peak exercise, as well as at the first ventilatory threshold (VT_1). Peak values were determined from the average of the last 20 s of the incremental test, while VT_1 was determined by visual inspection using the following detection criteria: (a) the workload level at which the VE starts to exponentially increase (VT_1-VE); (b) the workload corresponding to the first increase in the ventilatory equivalent of O_2 produced in the absence of a concomitant increase in $VE \cdot VCO_2^{-1}$ (VT_1-$VE \cdot VO_2^{-1}$); (c) the workload corresponding to the first increase produced in the end-tidal partial pressure of oxygen (VT_1-$PetO_2$) [32, 33].

Functional capacity was also assessed through the Six-Minute Walk Test (6MWT), as well as Chair Stand Test (CST) and Arm Curl Test (ACT). 6MWT was performed according the standard protocol recommended by the American Thoracic Society [34]. Briefly, the 6MWT test was conducted in a 30-m hallway marked every 5 m with tapes on the floor. Subjects were instructed to walk from end to end covering the longest possible distance for 6 min. When time elapsed, the distance covered was determined and recorded in meters. During CST, starting from a seated position, subjects were asked to complete as many full stands as possible in 30 s on a chair without arms with a seat height of 43 cm. During ACT, subjects were seated on a chair and asked to perform as many curls as possible through a full range of motion, using a hand weight (5 lbs for women and 8 lbs for men) within 30 s. For both CST and ACT, score was the total number of stands or curls respectively, executed correctly within the 30-s time limit [35, 36].

After the initial evaluations, patients were divided in two exercise groups, based on their level of physical fitness and comorbidities. Each group then performed 2 h of exercise per day, 1 h in the morning and 1 h in the afternoon. All sessions included 5–10 min of warm-up, 30–40 min of main work, and 5–10 min of cool-down and 5–10 min of stretching. For aerobic exercise, cycle ergometer or treadmill was the main modality, and intensity was set around VT_1, with individual adjustments according to perception of effort or other symptoms (e.g., joint pain). Exercises for muscle strength and resistance were performed with dumbbells, ankle and wrist weights, elastic bands, or the subject's own weight as a resistance. During each session, a total of 10–15 sets of 12–25 repetitions targeting the major muscle groups of the upper and lower body and the trunk were performed. As for aerobic exercise, intensity and volume were individualized. All functional tests (CPET, 6MWT, CST, ACT) were performed at admission, and repeated before discharge, to evaluate progress and adjust individual exercise indications, as patients were encouraged to continue regular exercise as part of an active lifestyle after the end of the MRP.

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Table 1. Baseline characteristics registered at the beginning of the rehabilitation programme in 259 patients consecutively admitted between January 1st, 2016, and April 1st, 2017 (young <65 years old vs. old >65 years old)

	Young	Old	*p* value
Total	215 (83)	44 (17)	
Age, years	48.2±11.5	69.3±3.5	<0.001
Male	70 (32.6)	16 (36.4)	ns
Female	145 (67.4)	28 (63.6)	ns
Body weight, kg	121.4±29.2	112±21.6	0.043
BMI	43.9±5.1	43.9±4.2	ns
Waist circumference, cm	130.4±18.6	129.3±14.9	ns
Neck circumference, cm	43.9±5.1	43.9±4.2	ns
Type 2 diabetes	51 (23.7)	14 (31.8)	ns
Hypertension	112 (52.1)	39 (88.6)	<0.001
OSAS	125 (58.1)	29 (65.9)	ns
NAFLD	173 (80.5)	42 (95.5)	0.016
Osteoarthritis	149 (69.3)	42 (95.5)	<0.001
CVD	75 (34.9)	34 (77.3)	<0.001
CKD	5 (2.3)	6 (13.6)	0.001
Psychiatric disease	43 (20.0)	6 (13.6)	ns
BED	14 (6.5)	0 (0)	ns

Data are presented as *n* (%) or mean ± SD. BMI, body mass index; OSAS, sleep apnea syndrome; NAFLD, non-alcoholic fatty liver disease; CVD, cardiovascular disease; CKD, chronic kidney disease; BED, binge eating disorder.

Statistical Analysis

Data are shown as means ± standard deviations for quantitative measures, and frequency percentage for categorical variables. Baseline clinical characteristics were compared in older and younger patients with the unpaired Student's *t* test for categorical variables and χ^2 test for categorical variables. The efficacy of the rehabilitation program was tested in each group comparing with Student's *t* test for paired data selected quantitative parameters collected at the beginning and at the end of the program. The percentage changes in the different parameters during the program were then calculated and the difference in percent changes between the two groups were tested by unpaired Student's *t* test. All statistical analyses were performed using the IBM SPSS Statistics 21.0 software.

Results

The study included a total of 259 adult patients, 215 aged <65 years (young; 70 males and 145 females, mean age 48.2 ± 11.5 years and mean BMI 43.9 ± 9.4) and 44 aged >65 years (old; 16 males and 28 females, mean age 69.3 ± 3.5 years and mean BMI 41.9 ± 6.9), consecutively admitted to the MRP between January 1st, 2016, and April 1st, 2017. Baseline characteristics of the two groups registered at admission are reported in Table 1. The old group presented a higher burden of comorbidities, with a significantly higher prevalence of hypertension (52.1 vs. 88.6%, *p* < 0.001), non-alcoholic fatty liver disease (80.5 vs. 95.5%, *p* = 0.016), symptomatic OA (69.3 vs. 95.5%, *p* < 0.001), cardiovascular disease (34.9 vs. 77.36%, *p* < 0.001), and chronic kidney disease (CKD; 2.3 vs. 13.6%, *p* = 0.001). Physical fitness was lower in the old group, who performed worse in all functional tests. In particular, they achieved lower peak PO (PPO: 101.5 ± 25.5 vs. 134.3 ± 42.3 W; *p* < 0.001) and peak VO_2 (VO_{2peak}: 16.1 ± 3.1 vs. 18.3 ± 4.5 ml/kg/min; *p* = 0.012), shorter distance at 6MWT (367.5 ± 116.1 vs. 441.7 ± 99.4 m; *p* < 0.001), and less repetitions on CST (11.5 ± 2.8 vs. 13.3 ± 4.0 stands; *p* = 0.005) and ACT (16.1 ± 3.4 vs. 18.7 ± 4.6 curls; *p* = 0,005).

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Table 2. Anthropometric, metabolic, and cardiovascular parameters registered at the beginning and at the end of the rehabilitation program (young <65 years old vs. old >65 years old)

	Young				Old			
	beginning	end	delta, %	*p* value	beginning	end	delta, %	*p* value
Body weight, kg	121.4±29.2	116.0±26.8	−4.3±1.8	<0.001	112±21.6	107.6±20.3	−3.8±1.7	<0.001
BMI	43.9±9.4	41.9±8.7	−4.4±2.2	<0.001	41.9±6.9	40.2±6.5	−3.9±1.6	<0.001
Waist circumference, cm	130.4±18.6	124.9±17.6	**−4.1±2.2***	<0.001	129.3±14.9	124.9±14.4	**−3.4±2.0***	<0.001
Neck circumference, cm	43.9±5.1	42.3±5.4	−3.5±6.4	<0.001	44.0±4.2	42.8±4.1	−2.7±2.0	<0.001
Fasting blood glucose, mg/dL	101.3±29.7	90.5±14.6	−8.1±12.9	<0.001	104.6±23.8	93.5±11.3	−8.3±13.5	<0.001
Creatinine, mg/dL	0.96±2.27	0.99±2.2	+7.0±16.0	<0.001	0.93±0.3	1.0±0.4	+8.0±16.4	0.014
Total cholesterol, mg/dL	182.7±34.4	154.2±31.8	−15.0±12.6	<0.001	179.3±37.4	151.7±29.9	−14.0±14.1	<0.001
LDL-cholesterol, mg/dL	108.8±29.2	89.7±27.5	−16.7±18.3	<0.001	105.0±32.5	84.4±25.9	−17.5±18.0	<0.001
HDL-cholesterol, mg/dL	48.2±15.2	42.76±12.5	−9.2±15.8	<0.001	50.5±17.7	44.1±12.2	−9.3±16.0	<0.001
Triglycerides, mg/dL	129.3±62.4	108.4±44.7	**−10.5±26.4***	<0.001	113.9±55.7	107.1±43.8	**−0.8±36.2***	ns
HbA1c, mmol/moL	42.1±11.5	39.8±9.5	**−4.7±4.9***	<0.001	43.4±10.0	41.9±8.2	**−3.0±4.1***	<0.001
Uric acid, mmol/L	6.5±1.5	6.9±2.1	+4.5±22.1	0.005	6.8±1.7	7.0±2.3	+2.8±18.5	ns
Systolic blood pressure, mm Hg	130.2±19.0	122.7±10.7	−5.4±11.1	<0.001	133.2±17.2	122.4±10.0	−7.2±9.4	<0.001
Diastolic blood pressure, mm Hg	77.9±11.0	72.9±7.7	−5.0±13.0	<0.001	78.3±12.1	73.3±6.1	−7.2±9.4	0.006
FFM, kg/m	66.0±15.3	64.3±14.4	−2.4±5.0	<0.001	63.6±13.4	62.4±13.1	−1.7±3.0	<0.001
FM, kg/m	55.1±19.1	51.5±17.6	−6.2±6.7	<0.001	47.7±13.2	44.4±12.0	−6.7±4.6	<0.001
TBW, L/m	49.5±12.3	47.7±11.1	−3.0±5.6	<0.001	48.1±11.7	46.4±10.4	−3.0±4.2	<0.001

Data are presented as mean ± SD. BMI, body mass index; HbA1c, glycated hemoglobin; FFM, fat-free mass; FM, fat mass; TBW, total body water; * *p* value <0.05 between the variation between the 2 groups.

Anthropometric and cardiometabolic parameters of the two groups at the beginning and at the end of the MRP are reported in Table 2. Both groups showed a statistically significant reduction in BW (young: −4.3 ± 1.8%, old: −3.8 ± 1.7%; *p* = 0.122), BMI (young: −4.4 ± 2.2%, old: −3.9 ± 1.6%; *p* = 0.110), WC (young: −4.1 ± 2.2%, old: −3.4 ± 2.0%; *p* < 0.05), and neck circumference (young: −3.5 ± 6.4%, old: −2.7 ± 2.0%; *p* = 0.115). In both groups, a significant improvement was observed in both Glc (young: −8.1 ± 12.9%, old: −8.3 ± 13.5%; *p* = 0.941) and HbA1c levels (young: −4.7 ± 4.9%, old: −3.0 ± 4.1%; *p* < 0.05), TC (young: −15.0 ± 12.6%, old: −14.0 ± 14.1%; *p* = 0.678), and LDL (young: −16.7 ± 18.3%, old: −17.5 ± 18.0%; *p* = 0.786). In the YOUNG group, only blood levels of TG significantly decreased (young: −10.5 ± 26.4%, old: +0.8 ± 36.2%; *p* = 0.054), while levels of uric acid increased significantly in both groups (young: +4.5 ± 22.1%, old: +2.8 ± 18.5%; *p* = 0.611). Moreover, both groups showed a significant decrease of HDL (young: −9.2 ± 15.8%, old: −9.3 ± 16.0%; *p* = 0.954), and an increase of creatinine levels (young: +7.0 ± 16.0%, old: +8.0 ± 16.4%; *p* = 0.728). Finally, a statistically significant reduction was observed in both systolic (young: −5.4 ± 11.1%, old: −7.2 ± 9.4%; *p* = 0.267) and diastolic blood pressure (young: −5.0 ± 13.0%, old: −4.42 ± 15.4%; *p* = 0.809). Data regarding body composition at the beginning and at the end of the rehabilitation program are also reported in Table 2. In both groups, a significant reduction in fat mass (young: −6.2 ± 6.7%, old: −6.7 ± 4.6%; *p* = 0.585), fat-free mass (young: −2.4 ± 5.0%, old: −1.7 ± 3.0%; *p* = 0.286), and TBW (young: −3.0 ± 5.6%, old: −3.0 ± 4.2%; *p* = 0.993) was observed.

Physical fitness parameters of the two groups at the beginning and at the end of the rehabilitation program are reported in Table 3. In the young group, a statistically significant improvement of parameters regarding both aerobic capacity (+6.2 ± 14.3% in absolute $VO_{2\,peak,}$ +10.8 ± 17.0% in $VO_{2\,peak}$/kg, +15.3 ± 30.5% in 6MWT) and muscle strength (+26.9 ± 25.1% in CST, +27.3 ± 27.3% in ACT) was observed. In the OLD group, an increase in the distance walked during 6MWT was observed (+28.7 ± 22.0%), with unchanged peak CPET parameters, while muscle strength increased similarly to the YOUNG group in both CST (+24.8 ± 30.5%) and ACT (+15.2 ± 19.6%). Regarding submaximal CPET parameters, a significant increase in PO at VT_1 (PO_{VT1}) was observed in both groups (young: +13.2 ± 21.5%,

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Table 3. Variation of functional performance between admission and discharge in the two groups (young <65 years old vs. old >65 years old)

	Young				Old			
	beginning	end	delta, %	*p* value	beginning	end	delta, %	*p* value
VO_{2peak}, mL/min	2,087±579.9	2,199±610.7	**+6,2±14,4***	<0.001	1,767±487.5	1,755±532.5	**+0.3±17.8***	ns
VO_{2peak}, mL/kg/min	18.3±4.5	20.2±5.1	**+10.8±15.1***	<0.001	16.1±3,1	16.6±3.8	**+4.0±18.2***	ns
PPO, W	134.3±42.3	146.6±47.3	+9.8±14.6	<0.001	101.5±25,5	106.1±32.8	+4.1±19.8	ns
VO_{2VT1}, mL/min	1,396±391.3	1,473±375.9	**+7.1±16.4***	<0.001	1,310±307,3	1,285±341.3	**−0.5±17.3***	ns
VO_{2VT1}, mL/kg/min	12.0±3.1	13.3±3.4	**+11.8±17***	<0.001	11.9±2.3	12.1±2.5	**+3.0±17.4***	ns
PO_{VT1}, W	72.5±25.9	80.0±26.9	+13.2±21.5	<0.001	60.74±14.1	64.6±15.5	+8.4±19.0	0.034
6MWT, m	441.7±99.4	495.4±101.5	+15.3±30.5	<0.001	367.5±116.1	405.9±118.2	+28.7±122.0	0.002
30s Chair Stands, *n*	13.3±4.0	16.6±4.2	+26.9±25.1	<0.001	11.5±2.8	13.9±2.9	+24.8±30.5	<0.001
30s Arm Curl, *n*	18.7±4.6	23.3±5.2	**+27.3±27.3***	<0.001	16.1±3.4	18.3±4.3	**+15.2±19.6***	<0.001

VO_{2VT1}, VO_2 registered at first ventilatory threshold; VO_{2peak}, VO_2 registered at the maximal exertion (each VO_2 value was expressed both in absolute terms [mL/min] and after adjustment for body weight [mL/kg/min]); PO_{VT1}, power output registered at first ventilatory threshold; PPO, power output registered at the maximal exertion; 6MWT, Six-Minute Walk Test; 30s Chair Stands, 30-s Chair Stands test; 30s Arm Curl, 30-s Arm Curl test. * *p* value <0.05 between the variation between the 2 groups.

Table 4. The percentage difference (or percentage delta) in psychometric tests regarding quality of life and nutritional behavior between the beginning and the end of the rehabilitation program (young <65 years old vs. old >65 years old)

	Young				Old			
	beginning	end	delta, %	*p* value	beginning	end	delta, %	*p* value
BES score	31.8±8.3	27.5±7.8	−13.5±6.02	<0.001	26.3±7.2	25.9±6.2	−4.4±15.4	ns
SF36-A score	50.7±22.2	62.3±22.8	+22.8±2.7	<0.001	46.4±21.5	53.0±22.0	+25.0±45.6	0.027
SF36-B score	53.3±20.8	65.8±21.0	+23.45±0.9	<0.001	53.1±20.2	63.2±16.5	+31.3±50.6	0.018
SF36-tot score	53.1±21.4	65.2±22.1	+22.7±3.2	<0.001	49.7±20.0	58.5±19.1	+27.6±44.7	ns

Data are presented as mean ± SD. BES, Binge Eating Scale; SF36, 36-item Health Survey.

old +8.4 ± 19.0%), while VO_2 at VT_1 (VO_{2VT1}) was significantly increased only in the young, both in absolute terms (young: +7.1 ± 16.4%, OLD: -0.5 ± 17.3%; *p* < 0.05) and after adjustment for BW (young: +11.8 ± 17.0%, OLD: +3.0 ± 17.4%; *p* < 0.05).

Regarding the perception of quality of life and alimentary behavior, the psychometric test showed that younger patients presented a statically significant improvement in all analyzed psychometric scales, while elderly patients presented only significant improvement in health-related quality of life (Table 4).

The comparison of the percent changes observed during the program between the two groups is also presented in Figures 1 and 2. We observed a statistically significant difference for WC, TG, and HbA1c, which showed a greater percent decrease in the young group (Fig. 1), and for VO_{2peak}, VO_{2VT1} (both absolute and relative to BW), and ACT, which showed a greater percent increase in the young group (Fig. 2).

Discussion

The aim of our study was to assess the short-term effect of an intensive 3-week inpatient multidisciplinary rehabilitation program including personalized nutritional, exercise, and behavioral interventions developed for patients with severe obesity, on cardiovascular risk
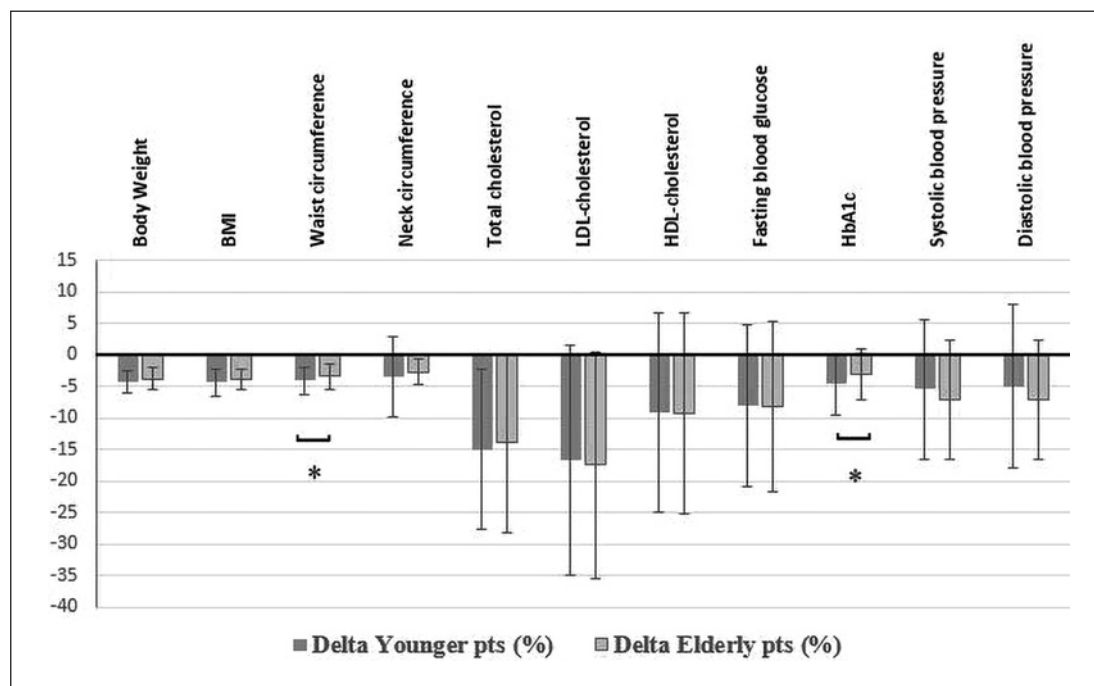
Fig. 1. Percentage differences (or delta) in anthropometric and metabolic variables from the beginning to the end of the rehabilitation program (young <65 years old vs. old >65 years old). pts, patients; BMI, body mass index. * $p < 0.05$.

factors and physical performance. The results of the study show a beneficial effect of the program in younger patients, as previously demonstrated [14], but most importantly, in elderly patients with obesity. This indicates that elderly patients respond positively to intensive rehabilitation in terms of weight loss and cardiovascular health, as well as of functional performance, which is fundamental for the prevention of frailty.

Despite the shortness of our intervention, we observed a significant improvement in cardiovascular risk factors in both young and elderly patients. Levels of Glc, HbA1c, TC, LDL, as well as SBP and DBP, decreased significantly, without differences between groups. We also observed a decrease in HDL, as well as a slight increase in creatinine and uric acid levels in both groups, which have been already reported during periods of acute caloric restriction [37, 38]. The overall improvement of the cardiometabolic may translate into better control of obesity-related comorbidities and reduced need for pharmacotherapy.

Aerobic capacity at the beginning of the program was lower in the elderly group, who achieved significantly lower PPO and VO_{2peak}, and walked a shorter distance on 6MWT. This represents an expected result, as aerobic capacity declines with ageing [39]. At the end of the program, we observed a minor improvement of peak CPET parameters in the elderly, accompanied by a significantly greater improvement on 6MWT compared to their younger counterparts. This result could be explained by taking into consideration the type, intensity, and duration of aerobic exercise performed. Elderly patients exercised at lower intensity, especially due to comorbidities, which limited the implementation of high-intensity exercise during the program. In addition, the duration of the intervention was sufficient for enhancing submaximal performance (i.e., PO_{VT1}, distance on 6MWT), but not enough to elicit changes in PPO or VO_{2peak}. Finally, elderly patients were more familiar with walking and, consequently, they preferred treadmill rather than cycle ergometer as the main exercise modality during sessions, which explains their substantial improvement only on 6MWT.
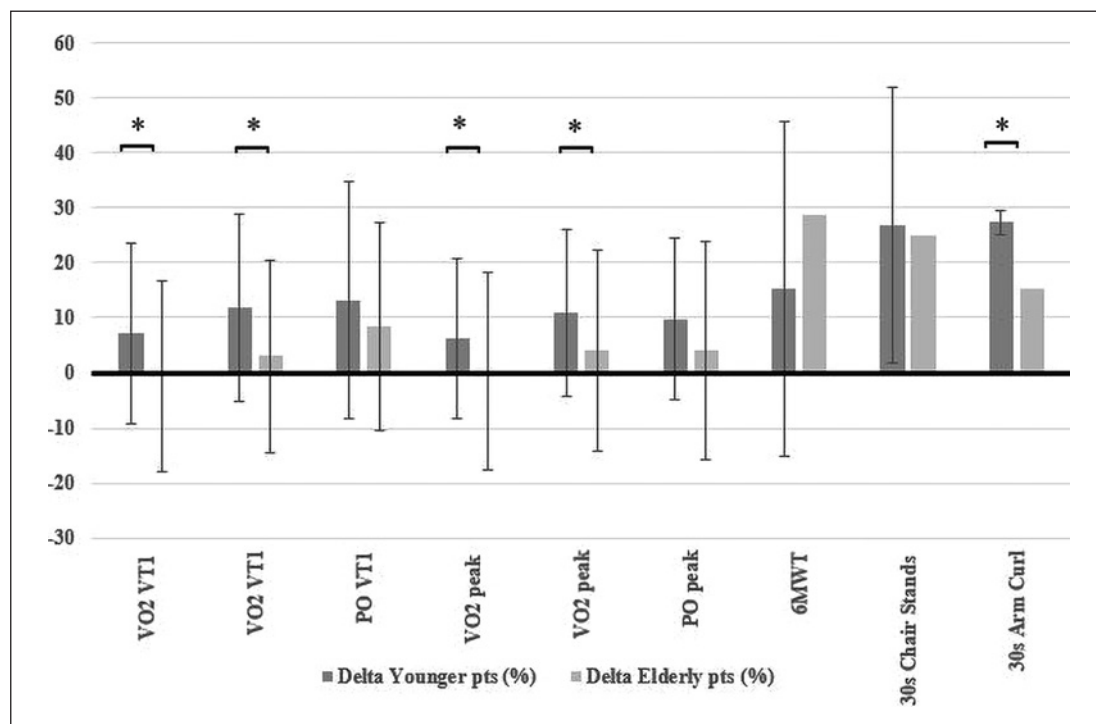
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Fig. 2. Percentage differences (or delta) in physical performance variables from the beginning to the end of the rehabilitation program (younger patients <65 years old vs. elderly patients >65 years old). pts, patients; $VO2_{VT1}$, VO_2 registered at first ventilatory threshold; VO_{2peak}, VO_2 registered at the maximal exertion (each VO_2 value was expressed both in absolute terms [mL/min] and after adjustment for body weight [mL/kg/min]); PO_{VT1}, power output registered at first ventilatory threshold; PO_{peak}, power output registered at the maximal exertion; 6MWT, Six-Minute Walking Test; 30s Chair Stands, 30-s Chair Stands test; 30s Arm Curl, 30-s Arm Curl test. * $p < 0.05$.

Regarding muscle strength of upper and lower extremities, at the beginning of the program elderly patients performed fewer repetitions in both ACT and CST. Both groups improved similarly their performance in CST, while elderly improved less in ACT. This result could be explained by the fact that during strength sessions of the elderly, more emphasis was given on lower limbs. The reason for this is because loss of muscle mass and function associated with ageing process begins from the lower limbs [40], with a consequent increase in falls in this population. Our results indicate that the implementation of muscular resistance exercise in patients with obesity may contrast muscle dysfunction, which is observed especially in the elderly. In the long-term, preserving muscle function in the elderly may prevent frailty and falls, as well as the consequences related to falls.

As the prevalence of obesity increases in all age groups, obesity in the elderly becomes an important public health problem that challenges and involves several health-care professionals and delivery systems. Our multidisciplinary rehabilitation program improved significantly the cardiometabolic profile and physical fitness in elderly patients with obesity, besides their higher prevalence of chronic diseases, which was in line with that observed in the general Italian elderly population [41].

Few studies investigated the effects of a lifestyle modification program as a therapeutic approach in elderly patients with obesity. Villareal et al. [42], using a 1-year randomized controlled trial, assessed the independent and combined effects of weight loss and exercise in obese adults over 65 years old. After 52 weeks, the study demonstrated that weight loss

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due to diet recommendations and exercise improved physical function and ameliorated frailty more than either weight loss or exercise alone, although each of those was beneficial. In a subsequent paper, Villareal and colleagues [43] showed that 18 months after the end of the previous trial, older subjects with obesity maintained the beneficial results, such as weight loss and improvement of metabolic and cardiovascular risk factors. Miller et al. [44] evaluated physical function and body composition in older adults with obesity and symptomatic knee OA after an intensive weight loss program including a daily caloric restriction of 1,000 kcal combined with physical exercise 3 days per week. After 6 months, the study showed a significant improvement of physical function and reduced symptoms. Furthermore, in a systematic review on the tolerance and effectiveness of physical exercise and weight loss for hip and knee osteoarthritis in elderly patients, Le Quintrec et al. [45] reported that land-based and/or aquatic exercise resulted in reduced pain and improved function in terms of walking speed and/or distance, a result which was more substantial with combined diet and exercise interventions. The importance of exercise as part of any weight loss program in the elderly was highlighted by Villareal et al. [46]. The authors concluded that the implementation of both aerobic and resistance exercise can be effective in improving functional status and prevent the age-related decline in bone and muscle mass, thus decreasing the risk of frailty. Considering all the above, although evidence-based data to guide the treatment of obesity in the elderly are limited, it seems to make little clinical sense to promote weight loss without the inclusion of physical activity [47, 48].

In conclusion, our study demonstrates the beneficial clinical and functional outcomes of a 3-week multidimensional therapeutic program including diet, exercise, and behavioral therapy in elderly patients with severe obesity. Our results, especially those regarding physical fitness, support the hypothesis that obesity-related frailty may be reversible. Considering the complex clinical status and comorbidities of older patients, which may limit bariatric surgery, a residential multidisciplinary context represents an optimal setting for the initial management of obesity in the elderly.

Statement of Ethics

Disclosure Statement

The authors declare no conflict of interest.

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