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Physical ability in bariatric surgery patients: results of the supervised and individual approach

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ABSTRACT

Introduction: Physical activity (PA), exercise, and lifestyle intervention are basic interventions to reduce short- and long-term surgical and non-surgical complications in bariatric patients. The purpose of our study was, first, to evaluate the importance of individualized, professionally guided training, encouraging PA, and subsequent positive effects of physical ability and body composition following a structured and supervised exercise program.

Methods: A total of 11 morbidly obese male (n = 4) and female (n = 7), aged 30–54 years, previously subjected to bariatric surgery, were recruited and subjected to 10-weeks structured and supervised exercise protocol with nutritional counseling and motivational support, consisting of twice weekly aquatic and outdoors training sessions. The same protocol was applied to the control group but without supervision, counseling and support. Blood analyses, basic anthropometric measures, body composition analyses, and physical fitness tests were performed before and after the exercise protocol.

Results: The weight, body fat, BMI, systolic and diastolic pressures were mildly decreased after the exercise program, while sit-to-stand, handgrip, and one leg stance scores showed mild increase after the exercise program.

Conclusion: Obese bariatric surgery patients may benefit from structured, supervised exercise program with nutritional counseling and motivational support. Further studies with larger number of participants are needed to confirm the results.

Key words: Bariatric surgery; morbidly obese; physical ability; body composition; nutritional counseling

INTRODUCTION

Increased morbidity and mortality from cardiovascular disease, type II diabetes, cancer, degenerative diseases of the musculoskeletal system, and reproductive and respiratory disorders are all concomitant to different grades of obesity and risk factors for obesity and disease-related complications (1). Besides, overweight and obese individuals tend to have more self-reported fall or fall-related injury, such as sprains, dislocations, and fractures (2) than individuals of healthy weight.

Bariatric surgery remains the most effective treatment to decrease and maintain weight loss, as well

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as to improve comorbidities and mortality (3,4) but only in a well-established lifestyle intervention, including dietary counseling and physical activity (PA). Dietary interventions and subsequent therapy, education, and maintenance of regular PA, behavioral therapy, pharmacotherapy, bariatric surgery, as well as combinations of these strategies (5,6) are needed to treat obese patients, to improve the level of individual health, and to treat concomitant diseases. The last two interventions are recommended as the first step to achieve weight loss and to reduce the influence of obesity-related comorbidities in subjects with severe obesity (7).

PA is an important component of lifestyle intervention (7) that allows long-term weight maintenance and also importantly improves the quality of life and the lifestyle in general. However, it bears to mention that authors seemingly interchangeable use the terms "physical activity" and "exercise" regardless the fact that they denote two different concepts. Briefly, PA classified into occupational, leisure, and household or other daily activities, attributes to any bodily movement produced by skeletal muscles that require an amount of energy to accomplish an activity. This amount can be measured in kilojoules (kJ) or kilocalories (kcal) (8). In contrast, exercise attributes to a subset of PA that is planned, structured, and repetitive and it is intended to improve or maintain components of physical fitness (8). It can be divided into aerobic exercise, resistance training, or combined aerobic and resistance training. We are aware that the terms mentioned denote two different concepts. However, in this paper, we decided to use them as synonymous as some of the studies to which we will refer operate with the terms interchangeably. Nonetheless, data have shown that improved cardiorespiratory fitness due to increasing pre-operative PA may potentially reduce short-term complications after bariatric surgery (9). Additionally, according to Donnelly *et al.* (10), consistent PA is the most important predictor of long-term weight loss maintenance.

To the best of our knowledge, there are no data available of evidence-based pre-operative PA guidelines for supervised structured PA that might be advised for general community of morbidly obese patients.

Therefore, an impact of small cross-sectional pilot studies in the population of morbidly obese patients might be an important approach to clarify physical abilities as well as the need for supervised, structured PA, combined with tailored and individualized dietary approach, for the purpose of favorable changes in body composition and improved health.

METHODS

Participants

A total of 11 morbidly obese male (n = 4) and female (n = 7), aged 30–54 years, who previously underwent bariatric surgery, were recruited from an existing database of bariatric outpatient service at our institution, and entered the study protocol after detailed medical examination. Obese patients from the diabetes database were offered the same exercise protocol but without target counseling, and they represented a control group. Recruitment took place from April 2015 to June 2015. Complete medical examination was carried out by a specialist in bariatric surgery, internal medicine practitioner, and kinesiologist.

The exclusion criteria were as follows: Body mass index (BMI) <35, physical inactivity as defined by the American College of Sports Medicine's (ACSM) guidelines (<60 min of structured or planned PA per week) within the past 6 months (11), cardiovascular and pulmonary disease, type 2 diabetes mellitus, musculoskeletal trauma and impairments, pregnancy or lactating women, and previous bariatric or digestive tract surgery. Other conditions that could affect study measurements (lipid-lowering medication, appetite suppressants, psychiatric medications at dosages known to alter weight, cigarette smoking, and alcohol consumption) were clearly evaluated. Initially, of 35 candidates who enter the study protocol, 20 of them dropped out according to medical circumstances, while the next 4 candidates withdrew during intervention due to non-health-related reasons. Written informed consent was obtained before participation and after intensive individual description of study design. The trial protocol was approved by The National Medical Ethics Committee of the Republic of Slovenia.

Study design

In the 1st week prior starting the training program, initial participant's physical ability was assessed by aerobic fitness test. All the rest of the tests and measurements were performed before and after completion of training program. The participants were subjected to 10-week structured and supervised training program with targeted counseling, consisting of aquatic training sessions (Table 1) and outdoors training sessions (Table 2).

Blood analyses

Following an overnight fast, a blood sample was taken and serum glucose, hemoglobin, sodium ion, potassium ion, creatinine, total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and triacylglycerol (TG) using standard methods in a certified laboratory.

Basic anthropometric characteristics

Basic anthropometric characteristics were obtained using standardized techniques and equipment. BMI was calculated as BW/BH^2 and classified according

TABLE 1. The structure of aquatic training session

1		2					3
Warming-up		Aerobic training					Cooling-down
Exercise	Duration (min0)	Exercise	Repetitions at the beginning of TP	Session number at the beginning of TP	Repetitions at the end of TP	Session number at the end of TP	Exercise
Warming – up	5	Jumping on the site in the shallow	20	2	30	2	Cooling- down
Joint mobility	2.5		20	2	30	2	
Stretching	2.5		20	2	30	2	
			20	2	30	2	
		Deepwater skipping	15	4	30	7	
		Kicking from the edge of the swimming pool	5+6+7+8 = 26 repetition	(4)	7+8+9+10=34 repetition	(4)	
		Abdominal muscles	20	3+3=6	35	5+5=10	

TP: Training program

TABLE 2. The structure of outdoors training session

1		2					3	
Warming-up		Aerobic and strength training					Cooling-down	
Exercise	Duration (min)	Exercise	Repetitions at the beginning of TP	Session number at the beginning of TP	Repetitions at the end of TP	Session number at the end of TP	Exercise	Duration (min)
Warming- up	5	Deep squat	11	3	21	4	Cooling-down	5
Joint mobility	2.5	Hips lifting off the floor	13	3	23	4		
Stretching	2.5	Heels lifting off the floor	15	3	25	4		
		Horizontal push	10	3	23	4		

TP: Training program

to the World Health Organization recommendations for adults (12) as follows: Normal weight within 18.5–24.9, overweight within 25–29.9, and obesity over 30.

Body composition

Bioelectrical impedance analysis (BIA) was performed with InBody 720 (InBody, Seoul, Korea) analyzer, using the following criteria: 1) Drinking and eating was not allowed 4h before testing; 2) normal body hydration had to be maintained before testing; 3) caffeine and alcohol were not allowed 12h before testing; 4) exercises were not allowed 12h before testing, 5) diuretics were not allowed 7 days before testing; 6) urination was not allowed 30 minutes before testing; 7) females perceiving retention of water during particular stage of their menstrual cycle were tested at different time point (13).

Physical fitness tests

Physical fitness tests were performed using handgrip strength test (Noraxon MyoTrace 400), 30 seconds Chair Stand Test (30-s CST), Young Men's Christian Association (YMCA) bench press test, and one-leg standing (OLS) test. Calibration of all instruments used was tested prior the testing. No verbal encouragements were performed.

Handgrip strength test

Noraxon MyoTrace 400 hand dynamometer was used to measure grip strengths after a period of standardized warm-up and familiarization with the dynamometer. In sitting position, participant held the hand dynamometer in the tested hand, with the arms stretched out to the side of the body at a 90° angle and every 20 s squeezed the handgrip as hard as possible. Both, dominant and non-dominant hand measurements were done. Participants performed three maximum attempts for each measurement. 1 min rests were given between each attempt, and hands were alternated to minimize fatigue affects (14). An average value of these trials was recorded.

30-s chair stand test

A standard chair (with a seat height of 44 cm) without a backrest but with armrests was used. Initially, subjects were seated on the chair with their back in an upright position and they were instructed to look straight forward and to rise after the "1, 2, 3, go" command at their own preferred speed. Their arms were folded across their chest. The 30-s CST consists of standing up and sitting down from a chair as many times as possible within 30 s. Similar ambient conditions were used for all participants (15).

YMCA bench press test

A warm-up of individual preference was introduced before starting the test. A 36.4 kg (80 lb) barbell was used for men and a 15.9 kg (35 lb) barbell for women, and as originally prescribed, placed on the chest (in the 'down position") with hands grasping the bar. The cadence set at 1 b/s was determined by the metronome. With each beat, the metronome's bar was either raised or lowered to achieve an overall lifting cadence of 30 reps/min. A controlled place was obtained all over the test. The observation period was closed (16) when the participant could no longer lift the bar or could not maintain the cadence.

The one-leg standing test

Equal testing conditions for all participants were performed: A smooth, hard wooden board, and the subjects barefooted (17). The participants were asked to decide on which leg they would like to stand just before starting the test. Starting with the position of a relaxed stance with their weight evenly distributed between both legs, with their eyes open, the participants were instructed to stand on the leg they have selected without using any assistant device and keeping their arms by their sides. After a period of 60 s, the test has elapsed, at the moment when the stance foot shifts or when the lifted foot was replaced on the board, whichever occurred first. The examiner stood close to the participants throughout the trial for the purpose to prevent falls or injuries (17,18).

Brachial artery blood pressure

Brachial artery blood pressure measurement was performed by the medical personnel using a standard aneroid sphygmomanometer following a 10 min rest.

Training program

Training program (Tables 1 and 2) was introduced and completed at the Faculty of Sport in Ljubljana and consisted of 2 times per week aquatic (aerobic exercises) and 2 times per week outdoors (aerobic vigorous and strength exercises) training sessions for 9 weeks. Each training session had a set of 45 active minutes (60 min of total exercise duration), meaning at least moderate exercise intensity or at least 60% of the participant's predicted maximum heart rate, defined as 220 beats per minute minus age. Exercise intensity for aquatic and outdoors session was progressively increased every 2 and every 3 weeks, respectively. Minimal rest time between each part within the training session was set according to participant's heart rate recovery, but it was, if necessary, individually prolonged. Participants were individually supervised by a kinesiologist and were taught to warm-up and cool-down for injury prevention.

Nutritional counseling and motivational support

The rationale for this approach stemmed from the personal interview started prior study. Namely, participants' food consumption data showed more than 4000 kcal/day intake, also higher carbohydrate and fat intake, and suboptimal protein intake - on average 0.5 g of protein per kilogram of body weight. Therefore, general nutritional counseling regarding the importance of dietary regimen that reduces total daily calorie (300–400 cal) and carbohydrate intake, glycemic load, muffas supplementation of saturated fatty acids, and protein-enriched food, self-preparation of high quality food, and introduction of eating scheme (only clear written recommendations to caloric, protein, and carbohydrate intake) were advised to maintain long term results. Pre-exercise diet supplements were suggested and based on average low carbohydrate (mediate glycemic index) and enriched protein content.

Motivational interviewing techniques on weight reduction and support to self-efficacy were performed even needed for patients with eating problems.

Statistical analysis

Data analysis was performed by A SPSS for Windows (ver. 21.0; SPSS Inc., Chicago, IL). Small sample Wilcoxon paired-sample test was used due to the small sample to exact p calculation.

RESULTS

Basic anthropometric characteristics and body composition

Altogether, 11 morbidly obese male (n = 4) and female (n = 7), aged 30–54 years, were recruited, of whom 63% were female. Observed anthropometric characteristics in the study population (male and female) are presented in Table 3 and Figure 1.

Blood profile

Pre-training plasma lipoprotein profile, focused on HDL-C (<1.4 mmol/L), was obtained and confirmed (64% and 9% of morbidly obese female and male, respectively). All participants had similar non-dyslipidemic baseline values that remained unaltered after completing the training program. Likewise, there were no measurable pre- and post-training changes in other blood markers.

Physical ability tests

Table 4 and Figure 2 present a comparison of physical ability parameters before and after the intervention in the selected cohort of morbidly obese participants and supports positive effects of PA alone, as participant's nutritional habits were not measurably followed after nutritional counseling.

At the end of training program, we observed an increase in static muscle strength (19.47% and 15.03%, respectively), improved functional capacity in 30 s CST, and a statistically significant decrease in the systolic pressure (126.7 mmHg vs. 125.9 mmHg;

TABLE 3. Basic anthropometric characteristics of male and female participants upon enrollment into the study

Parameter	Mean±SD	
	Male (4)	Female (7)
Age (years)	49.75±2.99	39.86±7.80
Height (cm)	182.10±8.73	164.64±7.13
Weight (kg)	136.08±12.32	115.76±26.08
Body fat (%)	37.93±9.26	50.51±3.95
BMI	41.48±7.79	42.37±7.59

SD: Standard deviation, BMI: Body mass index

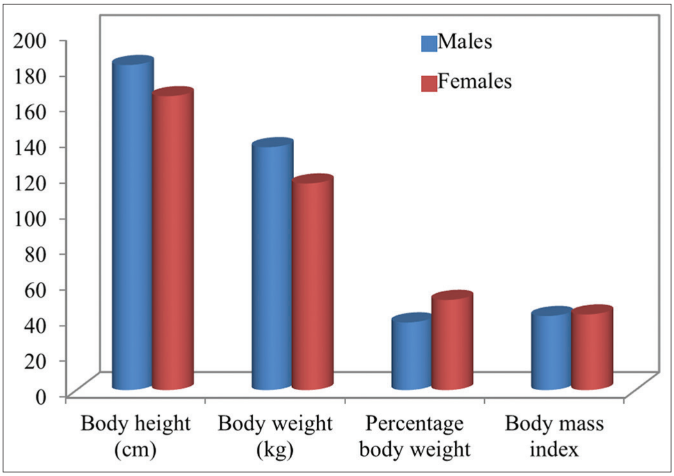

FIGURE 1. Basic anthropometric characteristics of male and female participants on enrollment into the study.

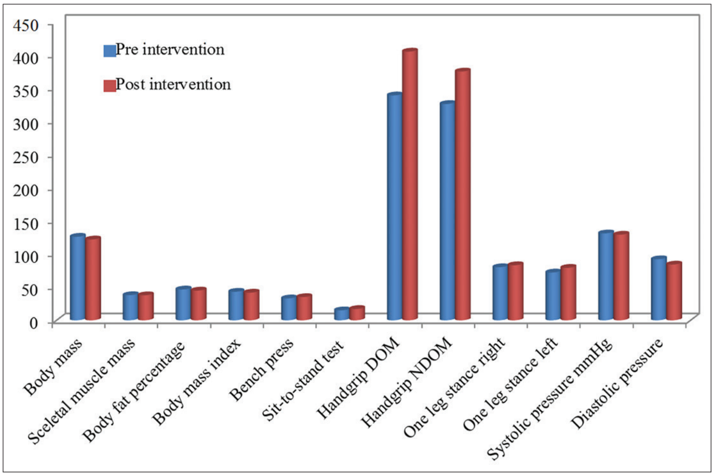

FIGURE 2. Physical ability parameters before and after programmed physical activity (PA) intervention (10-week training PA program).

$p < 0.047$). Regarding body composition, we found on average decrease of 3% of absolute body mass, representing on average 4% of excess weight loss (% EWL) (125.84 vs. 121.8 kg; $p < 0.054$). Statistically significant and important decrease in body fat percentage (46.43% vs. 44.73%; $p < 0.003$) indicated that this reduction mostly accounted to the visceral fat and other known fat deposits.

Nutritional counseling and motivational support

In the present study, a simple calculation showed that daily caloric reduction based only on motivational interview (MI) was even larger than the advised one, i.e., 300–400 kcal/day. Moreover, simple interview and counseling highly efficiently changed daily menu and reduced daily caloric intake, resulting in improved PA, stable weight, and slightly improved lean body mass. Besides the occasional use of meal replacements, participants exchanged and delivered food recipes to each other, and hence positively affected the whole group and helped to maintain participant's adherence. In the pre-operative period, participants followed the same diet regimen and had no dietary problems in the post-operative course. Moreover, within 6 months, an excellent post-operative weight reduction was observed with on average 56% of EWL.

TABLE 4. The influence of 10-week training program on physical ability parameters in participants before and after the intervention

Parameter	Mean±SD		Percentage change	P value
	Pre-intervention	Post-intervention		
Weight (kg)	125.84±24.39	121.8±24.16	−3.21%	0.054
Skeletal muscle mass (kg)	37.85±9.08	37.7±9.11	−0.40%	0.123
Body fat (%)	46.43±8.45	44.73±8.81	−3.66%	0.003
BMI	42.98±7.65	41.63±7.56	−3.14%	0.052
Bench press (kg)	33±12	35±15	6.06%	0.385
Sit-to-stand test	15±2	17±2	13.33%	0.008
Handgrip R (N)	339±117	405±122	19.47%	0.005
Handgrip L (N)	326±94	375±101	15.03%	0.001
One leg stance right (s)	80±44	83±49	3.75%	0.813
One leg stance left (s)	72±46	79±48	9.72%	0.203
Systolic blood pressure (mmHg)	126.7±9.8	125.9±11.1	−1.53%	0.047
Diastolic blood pressure (mmHg)	85.8±8.6	82.3±7.2	−8.70%	0.74

SD: Standard deviation, BMI: Body mass index

Participants were evaluated as having a good level of self-control despite different coping capacities and diverse sociodemographic and economic status. However, they needed support and transformation in their behavior. In addition, they regularly attended monthly psychological meetings that subsequently increased participant's self-motivation and positively affected as well as encouraged the whole group.

Comorbidities

Figure 3 shows participants' comorbidities prior entering into the training program. As noted, arterial hypertension was the most common one (5), followed by obstructive sleep apnea (OSA) (3) and gastrointestinal reflux disease (GERD) (3). The least frequent was polycystic ovary syndrome (2), urine incontinence (2), and depressive disorder (DD) (2). In the follow-up, all the comorbidities resolved.

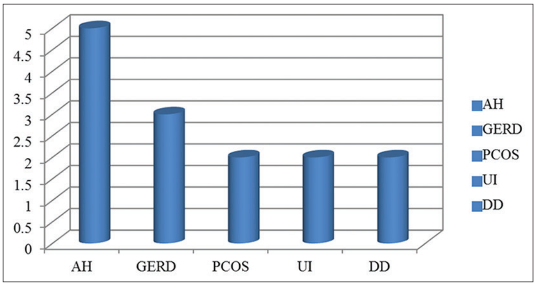

FIGURE 3. Comorbidities of the participants prior entering the training program.

DISCUSSION

An important improvement in basic anthropometric characteristics (i.e., body weight, body fat percentage, and BMI) has been found after supervised training program that highly supports the positive effect of PA on anthropometric characteristics reported in the previous studies. Baillot *et al.* (19) found quite similar results after supervised exercise training in 12 patients awaiting bariatric surgery with a significant reduction in weight (144.3 vs. 140.2 kg; $p = 0.07$), BMI (51.4 vs. 47.2 kg/m^2; $p = 0.004$), neck circumference (42.2 vs. 41.0 cm; $p = 0.016$), and fat mass (72.1 vs. 69.1 kg; $p = 0.026$). Funderburk *et al.* (20) designed a study protocol of 12-week supervised aquatic exercises with 5.0 kg reduction of body weight in the intervention group and 2.3 kg in the control group, but the paper was not conclusive to the statistical importance of these findings.

Marcon *et al.* (21) reported a significant decrease in body weight (−5.3 kg; $p < 0.001$) and BMI (−1.9 kg/m^2; $p < 0.001$) after 24 weeks of supervised low-intensity endurance training. This program may be suggested to the obese persons which are not candidates for surgical treatment. In contrast, Hickey *et al.* (22) found no body mass change with the 7 days of exercise training, presumably due to the short duration of a training program and the training program itself.

Despite numerous studies, studying the effects of exercise on morbidly obese, it remains unclear whether weight and fat mass loss are limited to aerobic or resistance approach alone or to the combination of both modes, therefore providing additive improvements in body composition. Regarding resistance training, some randomized controlled trials observed modest but statistically significant improvements in fat free mass, fat mass, and body fat pecentage (23). In addition, Guttierres and Marins (24) concluded that resistance training can effectively contribute to the reduction of risk factors related to metabolic syndrome, common in morbidly obese patients. Besides, ACSM (25), although recommend certain restrictions during resistance training, indorses that resistance training could be an important adjuvant of aerobic exercise, increasing strength, muscular endurance, functional autonomy, and increased skeletal muscle metabolism. In contrast, some authors reported a statistically insignificant trend (26,27) or no change in fat mass (28-30), respectively.

However, to explain the effects of aerobic and/ or resistance training on body mass and fat mass in overweight or obese adults, Willis *et al.* (27) designed a randomized control study with three exercise protocols, i.e., aerobic training, resistance training, and a combination of both modes. His findings stated that a program including resistance training is needed for increasing lean mass in middle-aged, overweight/obese individuals, while aerobic training alone is the optimal mode of exercise for reducing fat mass and total body mass. In congruence with these findings, we believe that fat mass decline in our survey is primarily associated with predominantly aerobic exercise training program, thus further strengthening the known effect of aerobic mode, i.e., a decrease of total fat body mass, significant fat compartment reduction, redistribution and a maintenance or slight increase in fat-free mass, and imply the importance of aerobic exercise in burning calories and losing body fat (30). Importantly, in accordance to the literature, this represents an important reduction of risk factor calculation immediately in the post-operative course and in short- and long-term. The impact of reduced free fat mass to endocrine regulatory function is clearly presented in the literature, those reducing calculated risk factors.

In contrast to land-based exercise programs (aerobic and strength), not much research has been carried out in the use of aquatic type of exercise. The latter was used by Annesi *et al.* (31) and Christiansen *et al.* (32), but only in association with aerobic training or other types of exercise. Therefore, the paper results might have been more persuasive if they provided clear conclusions about the impact of aquatic type of exercise alone. This might, to our opinion, be an important data, concerning a certain number of morbidly obese limitations in PA programs. Nevertheless, as suggested by Poston *et al.* (33), water could booster calorie expenditure without causing articular tissue overload, but we did not find any supportive evidence-based data. Since aquatic type of exercise might be the only possible one in superobese population as initial PA, our rationale to include this type of exercise into the training program was also, along with data observed at the time of PA introduction and patient interview, to reduce stress on lower extremities, to counter joint injuries, and to consider participants' health-related preferences.

As reported by previous randomized controlled trials, combined effects of exercise and diet on lipid profile are inconclusive (34,35). The reasons for this discrepancy are not entirely understood, but as stated by the authors may be related to the age, gender, baseline lipid and lipoprotein levels, intervention characteristics, changes in body composition, aerobic fitness, and nutrient intake. Given that these findings based on the usage of vote-counting approach, the results may be misleading and need to be interpreted with caution (36).

However, regarding our results, we found no appreciable differences in the lipid profile due to concurrent exercise and diet counseling. There are several possible explanations for this outcome. Our patients were obese, but metabolically healthy and this appears to be the most important factor for their unaltered lipid profile. The reason for inclusion of obese participants without dyslipidemia and with no or mild comorbidities was primarily to ensure participant's safety, as data about the physical abilities in this population are limited. In addition, comorbidities *per se* represent even higher risk in some population types with different anthropometric properties and also in lower categories of obesity.

Mild- or moderate-intensity aerobic activity in our training program might not have been intensive enough to detect any additionally favorable training-induced changes in the lipid profile, despite highly recommended in patients with comorbidities that do not allow resistant and high vigorous training. The latter one is a basic approach for efficient weight loss, and it can be reached only after a period of standard aerobic PA to avoid traumatic episodes in morbidly obese patients. This could also partly explain an unaltered response of HLD level to the exercise. Namely, studies reported an improvement in the HDL level only when sufficient threshold for intensity and/or duration of the exercise were reached (37,38).

Discrepancy between studies reporting increased (39,40), decreased (41), or unaltered HDL level (42) in response to intensities and durations in an obese cohort of patients of both gender may probably account to the inappropriate control of factors known to alter the lipid profile. However, in our group of patients, cigarette smoking and alcohol consumption, both known to may have a deleterious effect on lipids and lipoproteins (43), were the exclusion criteria. Therefore, along with probably insufficient exercise intensity level and in congruence with other studies (44), unaltered HDL might also account to the decrease in total fat intake and weight loss, despite the fact that only dietary counseling without direct food prescription was given.

With respect to other blood lipids, a meta-analysis of 70 studies reported that 1 kg of weight loss is associated with a decrease in TG and LDL-C (1.9 mg/dl and 0.77 mg/dl, respectively) (45). In contrast, our findings do not support these data, despite on average loss of 3 kg weight and statistically significant and important decrease of body fat percentage. The reasons for these rather contradictory results in our study are not entirely clear.

Regarding dyslipidemia, our work has led us to another important feature that appears to be clinically important for designing future randomized controlled trials. Namely, the prevalence and patterns of atherogenic dyslipidemia may vary across populations and ethnic groups (46) and may influence the approach: Diet prescription, PA training scheme, and surgical techniques in certain circumstances. Upto now, we did not have ethnically diverse population as the autohtonic population of today's Slovenian territory represents the population with the same anthropometric properties. The remaining minorities are extremely small and come from former Yugoslavia, Italia, or Hungry. However, being aware of different anthropometric properties, they have equal access to the health service and individual treatment protocols.

Nonetheless, in general, the impact of weight loss due to exercise and diet on blood lipid profile and subsequent risk reduction of metabolic syndrome is important. Weight reduction and secondary relationship to the level of TC, HDL-C, and apolipoprotein B are importantly involved in regulating insulin resistance, in the reduction of fatty liver disease due to obesity-related metabolic changes and in the improvement of endocrine effect of free fat mass to regulatory pathways and subsequent risk stratification reduction.

A meta-analysis of 27 studies based on aerobic exercise reported small but statistically significant effect on increasing HDL-C levels and related trend toward decreasing serum triglyceride levels (47); altogether represent an important risk reduction strategy for coronary artery disease, stroke, and non-alcoholic fatty liver disease due to inflammation-related disturbances. Overall risk reduction using FRAMINGHAM equation was reached through improvement in blood profile, systolic blood pressure, and improved waist-to-hip ratio, not specifically analyzed in the cohort of observed participants.

Taken together, although at present, the optimal amount of exercise as well as the optimal intensity for improving lipid levels is still unknown (48), and recommendations should be generally tailored to the individual to ensure patients' safety and should allow proper adjustment of the exercise program regarding participant's specific need.

The main challenge of dietary counseling is long-term weight loss maintenance that is strongly dependent on patient adherence. Therefore, to sustain and improve adherence to weight loss behavior, our pilot study underwent the supervision of diabetologist and kinesiologist with a medical degree, PA students with completed additional education in nutrition, psychologist, and a surgeon, especially focused and educated in nutrition. Support to tailored dietary counseling based on participant's capabilities, consultation and motivational support were provided through the participant-centered approach in all steps of programmed PA program.

In contrast to our adherence observations, several studies reported to have low adherence rates, even as low as 10% in a 12-month study (49). However, although the previous studies indicate inconsistent associations between social support and obesity-related health behaviors and outcomes (50,51), enhancing social support for behavior change may be critical for preventing long-term excess weight gain (52,53) and should be integrated into the weight loss programs. Namely, the great majority of obese people is more likely to experience a mood disorder, have low self-esteem, and report being socially isolated than leans one; that all can contribute to depression episodes enabling to sustain vicious, self-destructive circle, and adversely affect patient adherence, motivation, and commitment to change.

In addition, obese faces several motivational barriers. Jassil's pilot study (54) reported problems scheduling the time needed for exercise training into daily routine. However, individualized PA training might also be done in home circumstances with detailed instructions and support of media. We believe that approach could positively affect time limitation as reported to be the main reason for drop out and inability to attend sessions (54,55).

In addition, recent quantitative study involving 366 post-surgical patients demonstrated that obese also struggle with barriers specific to the bariatric population, i.e., difficulties in maintaining exercise behavior and problems with pain and chronic illness (18.6%) (56). In the present study, no such health problems were seen, probably due to the exclusion criteria.

We found an overall improvement in all physical ability tests. Especially, high level of PA-positive effects was noticed in handgrip strength and in 30-s CST. Furthermore, despite slight and statistically non-significant decrease in overall skeletal muscle mass, muscle response, expressed as a muscle strength per muscle mass, was improved. Several mechanisms at the cellular level could explain these findings. First, it is known that obesity is associated with a decrease in baseline capillary density and subsequently impaired muscle blood flow (57), an increase in the proportion of fast-twitch muscle fiber type, and altered neural activation patterns (58). Therefore, improved muscle response found in our study could be the result of exercise-induced neuromuscular activation (59,60), improved muscle architecture (61), fiber-type area (62), and increased high-energy phosphate availability (63). Second, fatty muscle infiltration is associated with reduced strength (64) as weight loss decreases muscle fat infiltration (65). Hence, muscle quality may improved also due to decreased muscle fat infiltration and reduced inflammation (66) as a result of weight loss. Indeed, studies have found an association between inflammation, muscle mass, and strength (67,68), meaning that loss of muscle fat may benefit through a decrease in inflammation (69).

Higher handgrip strength in the dominant hand led us to the assumption that the majority of participants were right-handed as most humans are right (70–95%) and a minority (5–30%) is left-handed (70).

After 9-week long training program, we found a statistically significant decrease in systolic and diastolic blood pressure, congruently with the blood pressure-lowering effects of PA found in other studies (22,71). Antihypertensive effects of PA are mediated by several mechanisms including neurohumoral, vascular, and structural pathways adaptations (72,73), and some of the postulated pathways for these effects are decreased catecholamines release, reduced total peripheral resistance, improved insulin sensitivity, and alterations in vasodilators and vasoconstrictors (73,74) In addition, reduced blood pressure could also accounted to the weight loss as several recent studies confirmed that a modest weight loss of 5–10% of initial weight, that is close to our results, *per se* has a pressure-lowering effect or even discontinues the need for antihypertensive medication (75,76).

In the follow-up, all of the comorbidities resolved. The results were expected as we included only metabolically healthy but obese participants without severe comorbidities. However, regular PA is associated with a lower risk of hypertension (73) and both acute as well as continuous PA even in moderate mode lower blood pressure in patients with hypertension (77,78). These antihypertensive effects of PA are also highly important for obese group of patients as hypertension is one of the most common obesity-related comorbidities (79), also confirmed in our study, and along with overweight presents an independent risk factor for cardiovascular disease (80).

A protective aspect of mainly aerobic PA against reflux and reduced number of GERD-related complications has been documented in patients suffering from clinically manifested GERD. (78,81,82), probably through the mechanism of an exercise-strengthened antireflux barrier (83). To the best of our knowledge, few data are available on the matter of eating habits and GERD symptoms. However, in our clinical practice, we found dietary counseling directly attached to the level of symptoms presentation, indicating that daily meal schedule from typical 1–2 meals/day to 5 meals/day, volume and carbohydrate load reduction, no night meals, and proper body hydration are all important for reduction of GERD symptoms.

Recent systematic review and meta-analysis reported that both PA and dietary approach are needed for reductions of apnea–hypopnea index (AHI), a key measure for OSA (84). Suggested hypotheses regarding the impact of increased PA and reduced AHI are improvement in muscle tonus of upper (85) airways and enhanced potency of pharyngeal muscles (86) among others.

Regardless of PA, one mechanism for improving OSA symptoms might also account through the weight loss and changes in weight distribution *per se* due to successful adherence to dietary counseling. This could explain also the resolved OSA in our study as decreased fatigue, sleepiness, and depressive symptoms have been found in even 5% of weight loss (87).

However, it is surprising that, after exercise intervention, OSA improved also in patients without concomitant change in mean body weight (86). As stated by Vgontzas *et al.* (88), this might account to the intervention's impact on alteration of the metabolic activity of central fat tissue.

Our study was limited by a small sample size, therefore diminishing the likelihood that a statistically significant results reflect a true effect (89) and making it hard to provide clinically useful conclusions. However, the survey was designed as a pilot one for larger randomized controlled trials in bariatric patients. Therefore, by increasing the sample size to at least 50–60 morbidly obese patients that undergo bariatric surgery per year with BMI ranging from 35 to the super obese, we will be able to expand our findings and increase statistical power of the study. Since the enrolled participants were neither hyperlipidemic nor had cardiovascular disease or other severe comorbidities, it would seem rational to include these types of patients into subsequent randomized controlled trials. Along with the awareness for precautions taken in these groups of patients to bypass health risks, this cohort group would probably benefit the most from our training program and would, expectedly, have fewer surgical and post-surgical complications due to multidisciplinary pre-operative weight loss program that continuously encourages all groups of obese patients in our bariatric outpatient service. Moreover, according to the results, at least 6-min walk test could be added to the pre-existing training program to evaluate individual physical capacity and intervention success to the expected weight loss effects in both genders. Its common use is mainly limited to the patients with chronic heart failure and pulmonary diseases to evaluate prognosis and treatment efficacy (90,91) and so far only a few studies have used it in obese (92,93).

Due to the results that highly support PA in groups with PA limitations, specially designed protocols should be prepared, i.e., any type of PA in these groups might represent also the implemented habit; an improvement in PA is expected after certain EWL (%) and therefore new designed PA for long-term results.

Despite relatively accurate estimation of body fat percentage using segmental body analysis, notably among high school-aged children (94,95), male wrestlers (96), and the elderly (97), BIA equations are population specific (98) and using single generic formula for accurate measurement of body fat percentage by segmental BIA models (99) may be misleading. According to some recent studies, the use in female populations is not valid (100,101) and net regional fat storage variations between genders (102) makes it more difficult to use.

As stated by Peterson *et al.* (99), future research regarding female population should be longitudinal with the purpose to determine whether the machines consistently over time or over/underestimate body fat percentage in individuals both with and without weight loss. These data suggest the development of user-friendly and widely available devices with more accurate predictions of body composition.

Third, training program was not designed in the manner of clear evaluation of aerobic capacity status, and thus, neither cycle ergometer nor indirect calorimetry measure maximal oxygen consumption (VO_2 max) was used. This all could have influenced the results obtained. Nonetheless, despite these limitations, our training program served as a tool for early detection and evaluation of physical ability in this cohort of participants and its usage for designing appropriate intervention strategies and PA protocols for the named population of morbidly obese population. Namely, inappropriately guided PA in morbidly obese patients might provoke health-related injuries, also seen in some of our patients at the bariatric outpatient service. In addition, to perform an effective intervention program, one of our setting goals of the study was also to evaluate participant's adherence to the training program and diet counseling as described in discussion.

We are aware that only general nutritional guidelines were given and neither basal metabolic rate measurements nor specific calorimetry equations for individuals sharing similar clinical characteristics was used (103). The latter due to the fact that might generate errors (104). Furthermore, we do not discuss other circumstances being importantly correlated to obesity, namely microbiota, and sleeping habits.

Despite these limitations, the goal of our approach was mostly adherence, patient education, and also highly recommended, not to rigid rules. However, although the participants were aware of recommendations given, they were not as efficient that they might be to achieve the purpose of optimal menu preparation, probably due to poor eating habits and they mostly prefer small number of averagely good recipes. This findings led us to the idea of preparing an e-prescription that will be applied in the next future. Moreover, by including an in-person support group, we could enhance patient's chances of pre-operative weight loss. Our expectations are supported by one of our previous observations, where self-motivated obese patients achieved greater pre-operative weight loss than less self-motivated; this might partly accounted to the improved self-esteem and to the positive impact of social support (family and nearby society encouragement). We are currently in the process of implementing widely available online video chat support group, as well as IT-devices for those patients who have busy schedules or cannot regularly be the part of an in-person support group.

CONCLUSION

Bariatric patients do benefit in terms of physical ability and body composition following a structured and supervised exercise program. Safe training, sufficient counseling, and education to community-level programs are needed and highly recommended for the goal of widely amenable and subsequently more efficient results in that cohort group of patients. It would be of high clinical and practical value to create a database with suggested tests of physical abilities along with the test normative values to combine results from different comparable studies. Long-term weight maintain and weight regain are in diet correlation to proper and individually tailored dietary counseling. Therefore, individual and patient-tailored nutritional support for reducing metabolic dysregulation and optimizing metabolic pathways is mandatory.

Although the measurement of self-esteem was not the goal of our study, it importantly improved and mostly correlated to patients' ability to PA and its positive effect to general health improvement. Implementation of new devices for body composition assessment into widely available, development of an online video chat support group, as well as IT-devices would improve patient adherence and long-term results. We are confident that our research will serve as a pilot for larger randomized controlled trials in bariatric patients.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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