Effects of Supervised Resistance Training on Fitness and Functional Strength in Patients Succeeding Bariatric Surgery

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Abstract
Huck, CJ. Effects of supervised resistance training on fitness and functional strength in patients succeeding bariatric surgery. J Strength Cond Res 29(3): 589–595, 2015—Evidence to support exercise training guidelines for patients who have undergone bariatric surgery is exceedingly limited. The purpose of this preliminary study was to evaluate the feasibility of a 12-week supervised, resistance training (RT) program and its short-term effects on physical fitness and functional strength for this population. A total of 15 patients with morbid obesity who underwent bariatric surgery participated in this quasi-experimental study. Patients were divided into 2 groups: 7 patients (age: 53.6 ± 8.2 years, body mass index [BMI]: 37.7 ± 6.3 kg m⁻²) in an RT program and 8 patients (age: 44.0 ± 9.7 years, BMI: 32.7 ± 4.2 kg m⁻²) following usual care; no group characteristics were significantly different at baseline. Changes in body weight, body composition, VO₂max (estimated, Ebbeling), flexibility (Sit-and-Reach Test), hand grip strength, and functional strength (sit-to-stand test [STS]) were assessed at baseline and after 12 weeks of follow-up. Adherence to RT was 84%, and no adverse events were reported. Both groups lost a significant amount of total body and fat mass; fat-free mass did not significantly change for either group. Flexibility and hand grip strength significantly improved in both groups; however, the improvements in flexibility for the RT group were significantly greater (p = 0.040). Only the RT group exhibited significant improvements in VO₂max (p = 0.025) and functional strength, STS (p = 0.002). In conclusion, supervised RT safely facilitates improvements in strength and physical functioning, increasing the patient’s capacity to perform activities of daily living after bariatric surgery.

Key Words morbid obesity, exercise, physical fitness, weight loss surgery, functional performance, bariatric surgery

Introduction
More than 40% of adults in the United States are currently considered obese or “extremely obese,” also known as morbid obesity (13). Morbid obesity, defined by having a BMI ≥ 40, currently affects over 18 million Americans, 6-times more than in 1962 (22). Although exercise and dietary interventions represent the predominate therapy for weight loss, these forms of behavior modification are often not successful in treating morbid obesity.

Bariatric surgery, however, has been shown to be very effective in reducing weight and limiting obesity-related comorbidities, such as diabetes, hypertension, sleep apnea, hyperlipidemia, and coronary artery disease (23). In 1991, the National Institute of Health released a consensus statement identifying bariatric surgery as the only means for sustainable weight loss in patients with morbid obesity and associated comorbidities (8). The United States has witnessed a dramatic increase in the use of bariatric surgical procedures during the turn of this century (28). Current data suggest that more than 120,000 of these procedures are performed every year (19).

Surgical interventions for patients with morbid obesity typically results in greater than 60% loss of excess weight (defined as body weight exceeding ideal body weight) as recorded over a 12-month follow-up period (10). A health concern for many patients after surgical intervention is loss of lean body mass and its potential impact on strength, functional performance, and resting metabolic rate (21,27). Loss of strength and increasing muscular fatigue may negatively affect the capacity to perform activities of daily living (ADL). This reduced ability to perform ADL can be detrimental to the quality one’s postoperative life. Although surgically induced excess weight loss (of an average of 60%) alone has been shown to improve physical functioning and mobility, most findings would consistently suggest that weight loss in combination with exercise training can elicit the greatest improvements in overall health and functional performance (18,21,24,25,27). In particular, weight training or resistance training (RT) has been shown to increase strength and attenuate muscle atrophy in adults with obesity who are adhering to caloric restriction for weight loss (3,14).
Another health concern for bariatric patients is the long-term sustainability of weight loss after the operation. Weight loss tends to peak 1 year after bariatric surgery (26). The total amount of weight loss decreases after that point, and significant recurrent weight accumulation may occur over longer periods of time (26). Patients have reported that participation in habitual exercise helped facilitate successful maintenance of their initial weight loss (11). The American Society for Metabolic and Bariatric Surgery and other related organizations provide recommendations for postoperative exercise. These recommendations, however, are very limited and lack scientific merit (9). This is largely due to the lack of evidence-based literature available to support the promotion of exercise training programs for patients who have undergone bariatric surgery. Therefore, this study was conducted to determine the appropriateness of a specifically tailored exercise training program for this population.

The primary aim of this preliminary, quasi-experimental study was to examine the effects of a supervised 12-week RT program on adherence and measures of physical fitness and functional strength in patients who have undergone bariatric surgery. It was hypothesized that this study population will successfully adhere to the RT program, which will elicit substantial improvements in functional strength. Furthermore, patients participating in the program will witness greater improvements in body composition, flexibility, and cardiorespiratory fitness (CRF) than a sample of well-matched controls—patients receiving usual postoperative care.

METHODS
Experimental Approach to the Problem
The study design was initially developed as a single-blinded randomized controlled trial; however, it was later deemed impractical to randomize the selection process of patients within a free-living community setting. Subsequently, a single-blinded quasi-experimental design was adopted. The postoperative patients were asked to complete the following: enroll in a 12-week progressive RT program or follow usual care (UC) guidelines, provide informed consent, and agree to participate in baseline and 12-week follow-up outcome measurements. All outcome measures, except strength testing, were performed by the principal investigator at the Health and Human Performance (HHIP) Laboratory at the University of Wisconsin–Stevens Point (UWSP). The RT program was administered at a private community-centered training facility, Adventure 212. The Institutional Review Boards at UWSP and Ministry Health approved this study.

Subjects
A total of 19 postoperative patients were passively recruited from the Ministry Health bariatric surgery program at St. Michaels Hospital in Stevens Point, WI, USA. An informational flyer was provided to all patients during post-surgery follow-up visits with a registered dietician. Once written informed consent was provided, health history records were reviewed to examine cardiovascular risk and determine eligibility. Patients were considered eligible if they successfully completed laparoscopic Roux-en-Y gastric bypass or banding/gastrorhaphy within the previous year, were 18–65 years of age, and were able to obtain a surgeon’s and a physical therapist’s clearance for the RT program. Patients were excluded if they planned to become pregnant, had a known presence of cardiovascular disease, had cancer in the previous 10 years, had uncontrolled exercise-induced asthma, used or planned to use steroids or anabolic supplements, had exercise limiting orthopedic injuries, was a smoker or used smokeless tobacco, had a history of alcohol or drug abuse, took diet pills, was currently enrolled in a structured exercise program, or planned to enroll in some other structured exercise program. All patients who met these criteria were invited to volunteer their participation in this study. Two patients were initially required to drop out of the study because of surgery-related health complications.

Procedures
Testing: Participants were asked to arrive to the HHIP laboratory in the morning after an overnight fast and to refrain from exercise for 12 hours before testing. All participants were tested at baseline and 12-week follow-up in the following order. Heart rate and blood pressure were measured using an automated cuff (OMRON Healthcare, Inc., Lake Forest, IL, USA) after 5 minutes of seated rest. Height was measured to the nearest 0.5 cm using a wall-mounted stadiometer (Seca, Hamburg, Germany). Body weight and percent body fat were assessed with a bioelectrical impedance analyzer, BIA (Tanita TBF-300A, Tokyo, Japan). When compared with underwater weighing, the leg-to-leg bioelectrical impedance system accurately assessed dietary and exercise-induced changes in fat mass (FM) and fat-free mass (FFM) in populations with obesity; no difference was found between measures (29). Furthermore, BIA was successfully used to monitor changes in the composition of weight loss for patients after bariatric surgery (20). Three waist and hip circumference measurements were obtained with a vinyl Gulick tape measure to the nearest 0.5 cm (the mean value was recorded) to elucidate regional adiposity via waist-to-hip ratio (WHR).

A combination of tests was used to assess various functional components of fitness, including: functional strength, maximal strength, flexibility, and CRF. The 5-repetition sit-to-stand (STS) test was used to evaluate functional strength. Although several variations of the STS test exist and its validity as a measure of lower limb strength has been questioned, it is widely used with special populations for various applications: strength, endurance, balance, and functional performance (5). In particular, the STS test with 5 repetitions (not 10 repetitions or 30 seconds) was specifically selected for this investigation for the following reasons: (a) most often used with older adults (5),
Maximal strength was estimated through the use of an isometric hand grip dynamometer (TWZ, Innsbruck, Austria). Each participant was asked to provide 3 maximal trials with each hand. The test was scored by taking the sum of the best trials (left and right) and dividing that value by the participant’s FFM, in kilograms. Maximal strength was also estimated through a repetition maximum (RM) testing with chest and leg press (Star Trac, Vancouver, WA, USA); however, only the RT group had access to the community-based training facility; therefore, the investigators were not able to obtain this measurement with the UC group.

Flexibility was assessed using the chair Sit-and-Reach Test (SNR), following the procedures outlined in Senior Fitness Test Protocol (17). Each participant was asked to perform 3 trials, and either a positive or negative score was recorded (to the nearest 1 cm) for the dominant leg. Cardiorespiratory fitness was estimated through utilization of the Ebbeling treadmill protocol (12). The Ebbeling protocol is a single-stage submaximal treadmill walking test that estimates an individual’s aerobic capacity. The self-selected walking speed, heart rate (measured by Polar electronic heart rate monitors), age, and sex were used to calculate an estimated $\text{VO}_2\text{max (ml kg}^{-1}\text{ min}^{-1})$. Finally, current levels of moderate-to-vigorous physical activity were assessed through administration of the BRFSS Physical Activity Questionnaire (version 2001) to control for any potentially confounding effects on the dependent variables (31).

### Table 1. Baseline descriptive characteristics of participants,*†

<table>
<thead>
<tr>
<th>Variables</th>
<th>Resistance training $(n = 7)$</th>
<th>Usual care $(n = 8)$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men/women</td>
<td>1/6</td>
<td>2/6</td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>$53.6 \pm 8.2$</td>
<td>$44.0 \pm 9.7$</td>
<td>0.695</td>
</tr>
<tr>
<td>Time since surgery (mo)</td>
<td>$4.3 \pm 1.7$</td>
<td>$5.9 \pm 2.7$</td>
<td>0.196</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>$101.6 \pm 19.8$</td>
<td>$92.5 \pm 15.5$</td>
<td>0.337</td>
</tr>
<tr>
<td>BMI (kg m$^{-2}$)</td>
<td>$37.7 \pm 6.3$</td>
<td>$32.7 \pm 4.2$</td>
<td>0.093</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>$114.8 \pm 20.5$</td>
<td>$108.8 \pm 12.3$</td>
<td>0.495</td>
</tr>
<tr>
<td>WHR</td>
<td>$0.89 \pm 0.07$</td>
<td>$0.91 \pm 0.08$</td>
<td>0.611</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>$44.4 \pm 5.4$</td>
<td>$37.7 \pm 9.5$</td>
<td>0.110</td>
</tr>
<tr>
<td>Isometric grip strength</td>
<td>$1.09 \pm 0.30$</td>
<td>$1.18 \pm 0.13$</td>
<td>0.397</td>
</tr>
</tbody>
</table>

*BMI = body mass index; WHR = waist-to-hip ratio; isometric grip strength = sum of forces (kilopond) of the left and right maximal grip force divided by fat-free mass (kg) of body weight.
†Data are expressed as mean ± SD.
$p$ values reported from independent t-tests.

Support and sensitivity are paramount when designing special considerations to optimize successful exercise adherence with this population. Wiklund and colleagues (30) conducted semistructured interviews with 18 patients awaiting bariatric surgery. They reported that these patients tend to be uncomfortable appearing in public wearing exercise clothing and that exercising with someone at the same level of health/fitness increased motivation (30).

Accordingly, the RT program implemented in this investigation was structured in the following manner: patients in RT were randomly assigned to small groups ($n = 5$), training was primarily conducted in isolated rooms, and training was facilitated and supervised by a supportive certified strength and conditioning specialist. The program was implemented in a relatively small community-based training facility, and the patients were offered low-cost, limited access to this facility for the duration of the intervention.

The frequency of the training program was 2 sessions per week for the first 6 weeks and progressed to 3 sessions per week during the final 6 weeks (12 weeks, 30 sessions in total). Each session lasted 60 minutes and included 10 minutes of a cardiovascular warm-up, 45 minutes of resistance training, and 5 minutes of a cool-down and stretching. The initial intensity level was 60% of the estimated 1 RM or an otherwise suitable intensity linking volitional fatigue with 8–12 repetitions; the intensity was gradually increased to 75%. Intensity was calculated from 5-RM testing conducted on the second day of the program. Each training session consisted of 8–10 exercises targeting all major muscle groups, and the volume within the number sets was gradually progressed throughout the program. Patients completed a single set for each exercise during the first 2 weeks of the program, 2 sets for weeks 3–7, and 3 sets for weeks 8–12. Rest periods between sets were intentionally minimized to 60 seconds or less by implementing small-group rotations through circuit training.

After a foundation of strength was established and technique was corrected, the patients were gradually exposed to a variety of RT modalities; including stack-weight equipment (Star Trac, Vancouver, WA, USA), free weights (Hampton Fitness, Ventura CA, USA), body weight, and resistive bands (Power Systems, Knoxville, TN, USA). A variety of modalities was implemented to foster and maintain high levels of enjoyment, engagement, and most importantly, adherence. Resistance-based water aerobics were substituted.
Resistance Training After Bariatric Surgery

Table 2. Changes in body weight and composition.*†

<table>
<thead>
<tr>
<th>Variables</th>
<th>Resistance training (n = 7)</th>
<th>Usual care (n = 8)</th>
<th>p†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>−8.8 ± 6.2§</td>
<td>−5.6 ± 5.3§</td>
<td>0.286</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>−3.3 ± 2.3§</td>
<td>−1.9 ± 1.9§</td>
<td>0.220</td>
</tr>
<tr>
<td>FM (kg)</td>
<td>−7.0 ± 4.5§</td>
<td>−4.0 ± 3.9§</td>
<td>0.191</td>
</tr>
<tr>
<td>FF (kg)</td>
<td>−1.8 ± 2.1</td>
<td>−1.5 ± 2.6</td>
<td>0.810</td>
</tr>
<tr>
<td>% Fat</td>
<td>−3.07 ± 1.8§</td>
<td>−2.45 ± 2.9</td>
<td>0.621</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>−9.6 ± 7.6§</td>
<td>−6.6 ± 8.1§</td>
<td>0.795</td>
</tr>
<tr>
<td>WHR</td>
<td>−1.8 ± 2.1</td>
<td>−1.5 ± 2.6</td>
<td>0.714</td>
</tr>
</tbody>
</table>

*§BMI = body mass index; FM = fat mass; FFM = fat-free mass; WHR = waist-to-hip ratio.
†Data are expressed as mean ± SD.
§Significant change for the variable within the group, dependent t-test, p ≤ 0.05.

Table 3. Changes in resting hemodynamics, strength, and physical fitness.*†

<table>
<thead>
<tr>
<th>Variables</th>
<th>Resistance training (n = 7)</th>
<th>Usual care (n = 8)</th>
<th>p†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting heart rate (b·min⁻¹)</td>
<td>−3.6 ± 5.5</td>
<td>−0.88 ± 9.4</td>
<td>0.519</td>
</tr>
<tr>
<td>Systolic BP (mm Hg)</td>
<td>6.9 ± 16.6</td>
<td>−0.25 ± 6.5</td>
<td>0.321</td>
</tr>
<tr>
<td>Diastolic BP (mm Hg)</td>
<td>1.4 ± 11.3</td>
<td>−1.75 ± 2.9</td>
<td>0.493</td>
</tr>
<tr>
<td>Flexibility (cm)</td>
<td>7.4 ± 4.2§</td>
<td>3.6 ± 3.8§</td>
<td>0.040</td>
</tr>
<tr>
<td>VO₂max (ml·kg⁻¹·min⁻¹)</td>
<td>0.91 ± 0.81§</td>
<td>0.46 ± 0.97</td>
<td>0.347</td>
</tr>
<tr>
<td>STS test (% change)</td>
<td>44.0 ± 15.2§</td>
<td>11.4 ± 23.8</td>
<td>0.006</td>
</tr>
<tr>
<td>Hand grip (% change)</td>
<td>11.3 ± 8.9§</td>
<td>11.6 ± 4.3§</td>
<td>0.419</td>
</tr>
</tbody>
</table>

*†BP = blood pressure; VO₂max = maximal oxygen consumption; VO₂max was estimated with the Ebbeling treadmill protocol; STS = sit-to-stand test.
‡Data are expressed as mean ± SD. Flexibility was measured via the Sit-and-Reach Test.
§Significant change for the variable within the group, dependent t-test, p ≤ 0.05.

for 1 day of land-based training modalities during the final 6 weeks of the program. Participants were instructed to exercise through full range of motion and to avoid the Valsalva maneuver. Patients in both groups (RT and UC) were encouraged by clinicians from the Ministry Health Bariatric team to increase daily physical activity and to consume protein shakes to attenuate losses of FFM resulting from the rapid weight loss.

Statistical Analyses
All analysis was conducted using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA). An independent t-test was used to examine between-group differences in anthropometrics and fitness components at baseline and during the 12-week follow-up. Changes for all dependent variables within groups were assessed with a dependent t-test. Pearson bivariate correlation coefficients were used to elucidate relationships between the various measures of physical fitness. An a priori alpha level of p ≤ 0.05 was used to determine significance, and all data are presented as mean ± SD.

Results
There were no significant differences between the groups at baseline, including age, sex, body weight and composition, grip strength, and duration of time since surgery (illustrated in Table 1). Self-reported levels of moderate-to-vigorous physical activity did not differ between groups at baseline (RT: 22.3 ± 20.5 METhrs·wk⁻¹ vs. UC: 16.5 METhrs·wk⁻¹).

The effects of the intervention on anthropometric measures and body composition are shown in Table 2. Both groups lost a significant amount of initial body weight and FM, accompanied by a decrease in waist circumference; however, these changes did not significantly differ between groups. Fat-free mass and WHR did not significantly change for either group. The ratio of the change in body mass (FM/FFM) was 6.2 ± 5.2 and 3.2 ± 3.7 (mean ± SD) for the RT and UC group, respectively, although these changes were not significantly different (p = 0.220).

The effects of the intervention on resting, noninvasive hemodynamics, and measures of physical fitness are shown in Table 3. There were no significant changes in resting heart rate or resting blood pressure. The SNR flexibility and hand grip strength significantly improved for both groups; however, the improvements in flexibility for the RT group were significantly greater (p = 0.040). Only the RT group exhibited significant improvements in VO₂max (p = 0.025).
and functional strength when measured via STS ($p = 0.002$). The changes in functional strength for the RT group were significantly related to changes in grip strength ($r = 0.842$, $p = 0.018$), SNR flexibility ($r = 0.815$, $p = 0.48$), and moderately related to $V_{\text{O}2\text{-max}}$ ($r = 0.719$, $p = 0.069$). Participants in the RT group demonstrated significant improvements in upper-body strength (30.7 ± 2.4%) and lower-body strength (22.5 ± 4.7%), mean ± SD, which is illustrated in Figure 1. Changes in strength, when estimated with 5-RM chest or leg press, were not significantly related to changes in grip strength or functional strength. Self-reported moderate-to-vigorous physical activity significantly increased only for the RT group (RT: +23.3 ± 17.7% vs. UC: +6.2 ± 13.3%); the difference between mean changes in group physical activity levels was significant ($p = 0.026$).

**DISCUSSION**

The preliminary goal of this investigation was to determine whether patients succeeding bariatric surgery would successfully adhere to a 12-week RT program. Because there are no standardized guidelines to determine the appropriate exercise prescription for postoperative bariatric surgery patients, the suitability of this study’s training program was carefully examined. The results from this investigation suggest that the supervised RT program was feasible and appropriate. The postoperative patients participated in 84% of the training sessions, and no adverse events resulted from the training. Adherence rates from previous studies implementing exercise training in populations with morbid obesity have ranged from 50 to 80% (1,2). Supervision, small-group training, facility accommodations, low-cost accessibility, and a variety of structured exercise modalities with gradually applied progression are some specific program considerations that may explain the high adherence rates for this investigation. In a recent qualitative investigation, patients awaiting bariatric surgery reported being uncomfortable with appearing in public wearing exercise clothing, and that they would prefer to exercise together with someone at a similar level of fitness (30). Addressing these concerns within our program likely provided support for sustainable levels of self-efficacy and motivation, key contributing factors for consistent adherence.

The effects of RT on weight loss, body composition, physical fitness, and functional strength were also examined. After 12 weeks, both groups (RT and UC) lost a significant amount of total body mass and FM, with no significant difference found between groups, illustrated in Table 2. Previous studies have also reported similar findings. Stegen et al. (27) examined the effects of combined endurance and strength training on body composition when compared with an untrained group during the first 4 months after gastric bypass surgery. They reported that both groups evolved equally with regard to decreases in FM and FFM (27). Another investigation used self-reported data to classify postbariatric patients as exercisers or nonexercisers (20). Within each interval, 0.75, 1.5, 3, 6, 9, and 12 months of follow-up, there were no differences in the percent changes in weight loss between the groups (20). It is plausible that the effects of the surgery or adherence to dietary changes are the primary factors that impact the total amount of weight or fat loss.

As illustrated in Table 2, neither group in this study lost a significant amount of FFM. The ratio of the changes in body mass (FM/FFM) was more favorable in the RT group than in the UC group, 6.2:1 vs. 3.2:1, respectively. Although these changes were not significantly different, they likely explain why only the RT group had a significant decrease in percent body fat. In contrast, Stegen et al. (27) reported significant decreases in FFM for patients during a 4-month follow-up, regardless of training status. The ratio of the changes in body mass (FM/FFM) were 3.2:1 for the trained group vs. 2.5:1 for the untrained group. The difference in body mass alteration between these studies is likely due to the timing of exercise intervention after surgery; greater amounts and more rapid weight loss are expected during the first 4 months after surgery. Most of the patients in this current investigation were beyond 4 months of postoperative care (Table 1). Dissimilar training modalities, physical activity, and/or protein consumption may also explain the difference in body mass alteration between these studies. It is also interesting to note that whether FFM can be completely preserved through RT in obese adults during periods of substantial weight loss is not fully understood (14,16).

The most profound effects of the RT program were the measurable changes in physical fitness and functional strength. These findings suggest that RT after bariatric surgery promotes greater improvements in flexibility, CRF, and functional strength than surgery alone. Although RT did
not completely attenuate muscle atrophy after surgically induced weight loss, it induced significant increases in functional strength (Table 3) and dynamic strength (Figure 1). Interestingly, these findings parallel the effects of RT in adults with obesity when adhering to calorically induced weight loss (14). Limited evidence exists to support these findings within the post-bariatric surgery population. Stegen et al. (27) also found greater improvements in functional and dynamic strength when patients adhered to an exercise program (combination of endurance and strength training performed thrice a week) after bariatric surgery. They reported greater increases in dynamic strength (quadiceps +72% and hamstrings +27%); however, they used a longer training regimen and different measures of strength (27). Alternatively, supervised exercise training (combination of endurance and strength) has been used in subjects with morbid obesity awaiting bariatric surgery (2). This exercise program exhibited high satisfaction rates among the subjects and resulted in significant improvements in physical fitness and quality of life, even with modest adherence rates, 57% (2).

Physical function improvements have also been shown with patients after bariatric surgery without participation in a structured exercise intervention (21). Within 3, 6, and 12 months of follow-up, patients had significant improvements in a battery of physical performance tests, including chair rise time, lateral mobility, gait speed, and knee strength (21). It is important to note, however, this investigation did not control for the potential interaction effect of physical activity. Observational evidence with self-reported physical activity suggests that physical activity levels typically increase after bariatric surgery, and that physical activity is related to the amount of weight loss (15). Consequently, improvements in physical functioning are likely dependent on surgically induced weight loss and increases in physical activity. In this investigation, weight loss did not differ between groups and moderate-to-vigorous physical activity increased in the RT group in response to the structured exercise program. Therefore, improvements in physical fitness and functional strength likely resulted from the RT regimen. And, most importantly, these respective improvements in dynamic strength, functional strength, flexibility, and CRF will likely result in an increased capacity to perform ADL, thus enhancing quality of life after bariatric surgery.

Several limitations should be considered when interpreting the results of this study. First, the small sample size, and the lack of randomization of patients into groups, may limit the generalizability of these findings for all patients after bariatric surgery. In general, it is challenging to recruit a large, randomized population in a relatively small rural community setting; only a limited number of surgeries can be completed within a specified amount of time. Second, caloric intake and protein consumption were not directly measured in this investigation, therefore the role that these variables have on the dependent variables could not be determined. Third, evidence for the reliability and validity of several aspects of physical testing is rather limited for this population, including: bioelectric impedance analysis for body composition, STS test for functional strength, and treadmill protocols for estimation of $V_0_{2max}$.

**Practical Applications**

Resistance exercise may feasibly and efficaciously be implemented to improve strength and physical fitness for patients succeeding bariatric surgery. Currently, there is very limited research available to illustrate the potential efficacy and/or effectiveness of exercise training regimens for these patients. These preliminary findings provide the foundational framework for future application of resistance exercise training suitable to the specific needs of this population. This study's training program exhibited strong adherence to RT in a population generally reported to experience many obstacles to being physically active (30). Furthermore, significant improvements in functional strength, CRF, and flexibility are indeed achievable with patients under rigorous caloric and/or food restrictions. This information is applicable for various health professionals. It is particularly useful for personal trainers, fitness specialists, health coaches, and clinical bariatric teams who facilitate health enhancement with this population. Additional research studies with larger sample sizes, longer training programs, and measurement of clinical outcomes are strongly warranted.

**Acknowledgments**

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**References**


