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Effect of Rapid Body Weight Loss on Balance and Functional Mobility in Obese Individuals after Laparoscopic Adjustable Gastric Banding Operation[*]

Meral KUCUK YETGIN[1†], Shahla RAY[2], Halit Eren TASKIN[3], David Michael KOCEJA[4], Koichi KITANO[4], James Bradley RAY[5], Wilhelmina RAVER[4]

[1]Marmara University Faculty of Sport Sciences, Department of Coaching Education, Istanbul, TURKIYE.
[2]Maryville College, Division of Natural Sciences, TN, USA.
[3]Istanbul University Cerrahpasa Medical Faculty, Department of Surgery, Istanbul, TURKIYE.
[4]Indiana University School of Public Health, Department of Kinesiology, Bloomington, IN, USA.
[5]Mayo Clinic Care Network, Blount Memorial Hospital Alcoa, TN, USA.

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Abstract

The purpose of this study was to evaluate the effect of rapid weight loss on static balance and functional mobility among excessively obese patients undergoing Laparoscopic Adjustable Gastric Banding (LAGB) surgery. Subjects (8 females; BMI >35 kg/m2) underwent baseline measurements before LAGB surgery, followed by subsequent evaluations at 6 weeks, 12 weeks, and 24 weeks during the follow-up appointments. During each evaluation, various assessments were conducted, including measurements of anthropometry such as body weight, height, hip and waist circumference, as well as functional tests for static balance, 10-meter walk, and timed get-up-and-go. There were statistically significant changes in weight, BMI, waist circumference, hip circumference, abdominal circumference, waist-hip ratio, static sway eyes open, timed up-and-go, 10-meter walk, and steps in 10-meter walk test values ($p<0.001$) between the baseline and the postoperative measurements. However static sway values under eyes closed condition were not statistically significant. In the 24-week follow-up, the weight loss, reduction in abdominal circumference, increase in walking speed against time and step count, and recovery in functional movements were shown to persist. Also, reduction in static balance surface oscillation confirmed the improvement of balance control.

Keywords: Static balance, Functional mobility, Bariatric surgery, Obesity, Rapid body weight loss.

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[†] **Corresponding Author:** Assoc. Prof. Meral KUCUK YETGIN, **E-mail:** meral.kucukyetgin@marmara.edu.tr

INTRODUCTION

The escalation in the prevalence of obesity has persisted globally, with developed countries experiencing a significant rise. In the United States, it has been reported that over two-thirds of the adult population is classified as overweight, and clinical obesity is evident in one-third of the adult population (World Health Organization, 2021). Unfortunately, diet therapy has been shown to be relatively ineffective in the long-term management of obesity. Furthermore, no truly effective pharmaceutical agents are currently available to treat obesity, particularly morbid obesity (English & Williams, 2018). It was found that at the end of a 2-year follow-up period surgically treated patients experienced a mean weight loss of approximately 20 kg more than their counterparts who received non-surgical treatment (Schauer et al., 2012). The detrimental impact of obesity on an individual's quality of life is well documented, however, literature suggests that significant improvement in quality of life can be achieved through bariatric surgery (Kushner & Foster, 2000). Bariatric surgery has been shown to improve physical activity levels among subjects, thereby fostering the adoption of a healthier lifestyle (Sjöström et al., 2004).

From a morphological perspective, obesity is identified by the excess accumulation of adipose tissue (Basdevant, 2008). This additional fat mass is distributed unevenly across different regions of the body, with obese individuals exhibiting trunk fat mass increase, particularly in the abdominal region (Mignardot et al., 2013). Obesity results in restrictions to daily activities due to an increase in the mass of body segments and alterations in body proportions. The postural instability of obese individuals has been reported under both eyes-open and eyes-closed conditions during quiet standing (Maktouf et al., 2020).

Prior studies have shown that bodyweight is a robust indicator of postural equilibrium. Elevated body mass index (BMI) has been associated with augmented postural sway in the dynamic, static, and perturbation-based assessment of balance training (Alice et al., 2022). Obesity is associated with structural and functional limitations that have been shown to affect balance and gait patterns (Cau et al., 2014), indicating that obesity may be an independent risk factor for falls (Himes & Reynolds, 2012; Wu et al., 2012). According to a systematic review of weight status and falls, BMI is not a valid predictor of fall risk (Moore & Boltong, 2011). However, there are studies showing a strong correlation between lack of balance and fall risk, especially in the elderly population. The relationship between body weight and balance control was first noted by Fregly et al. in 1968, who used balance testing to show that this relationship is especially prevalent in individuals with excessive abdominal circumference, (e.g., endomorphy, Błaszczyk et al., 2009). The literature presents substantial evidence demonstrating a significant correlation between obesity and balance impairments (Alice et al., 2022). Because of excessive fat mass in the abdominal region of obese individuals, the body’s center-of-gravity is shifted forward. However, there is insufficient research to better understand the relationship between obesity and balance control (Błaszczyk et al., 2009; Kerkez et al., 2013; Matrangola & Madigan, 2011; Miller et al., 2011; Teasdale et al., 2007). In individuals with obesity, the proportionate degree of musculoskeletal strength required to achieve equilibrium escalates given the increased mass to be managed. Greater body weight in those with obesity and extreme obesity is positively correlated with balance disturbances, potentially elevating the risk of falls (Hue et al., 2007; Hue et al., 2008; Matrangola & Madigan, 2011). These authors present compelling evidence that a reduction in body weight is associated with enhanced balance control. Their findings indicated that roughly 50% of the variability observed during regular bipedal quiet stance can be attributed to body weight (Teasdale et al., 2007). In summary, above-mentioned results indicate that weight plays a significant role to predict fluctuations in balance regulation. Losing weight is vital in mitigating co-existing medical conditions in individuals with morbid obesity and in promoting overall health in those who are obese. Individuals who are classified as overweight or obese exhibit lower functional capacities compared to individuals with normal weight (Vincent et al., 2010). Indeed, faster oscillations in young obese and overweight groups compared to their healthy weight counterparts indicate a strong relationship between weight and postural instability (Dutil et al., 2013; Hue et al., 2007). Notably, significant improvement in balance control was observed in overweight and obese individuals after significant weight loss. A positive correlation was established between the degree of weight loss and the recovery in balance control (Hue et al., 2007).

The capability of humans to maintain equilibrium during bipedal standing is crucial for the successful and efficient completion of numerous daily tasks (Horak, 2006). Maintaining postural control on an unsteady support surface is vital for daily routines as well as athletic performance. Despite the widespread recognition of the crucial role of balance proficiency not only in sports but also in fall prevention, a limited number of studies have investigated the impact of rapid weight loss on balance and functional mobility.

As previously shown, obese patients may experience variable information from certain sensory receptors, which may result in impaired postural control (Dutil et al., 2013; Hue et al., 2007; Teasdale et al., 2007). The inhibition of visual stimuli resulted in a more pronounced modification of postural control in individuals with obesity compared to those with normal body weight. Balance refers to the capacity to effectively regulate the center-of-mass with respect to the orientation of the body (Shumway-Cook & Woollacott, 2007). Obese individuals tend to have a center-of-mass that is more anterior than the typical population, which likely has an impact on its relationship to the base of support.

In recent years, bariatric surgery represents the most efficacious intervention for individuals with severe obesity. Consequently, there has been a steady, global rise in the number of severely obese patients undergoing this surgical procedure (Buchwald & Oien, 2009). Among bariatric procedures, LAGB is a pure gastric approach because only the stomach is involved in surgery and the intestinal anatomy is not altered (Wang et al., 2019). Leading to a decrease in body weight, a reduction in overall caloric consumption resulting from persistent behavioural modification is noted. The ideal weight loss with this method is 0.5 kg per week (McBride & Kothari, 2011), while the patients lose 58-60% of excess weight within 7-8 years postoperative (Freeman et al., 2011). Postural control and equilibrium can undergo changes due to the sudden shift in weight distribution, body composition, and center-of-mass in individuals with obesity. This study can illuminate the control of balance in obese individuals and the effects of bariatric surgery on balance during the weight loss period immediately after surgery. The aim of the present study is to assess the impact of accelerated reduction in body mass on stationary equilibrium and dynamic movement abilities in severely obese individuals post LAGB surgery.

METHODS

Participants

Subjects included 8 female patients (age 28 -53 years), diagnosed with obesity (BMI >35kg/m^2, obesity class II and class III) who underwent Laparoscopic Adjustable Gastric Banding (LAGB) surgery at the Center for Advanced Laparoscopic and Bariatric Surgery, Bloomington Indiana. All subjects were recruited on a volunteer basis. A single surgeon employed a standardized, community-based procedure to insert all gastric bands. Each patient completed the National Institutes of Health's bariatric surgery requirements. The National Institutes of Health (NIH) created standards for bariatric surgery eligibility in 1992 which are still commonly followed. These criteria state that individuals who are eligible for bariatric surgery should met the criteria of BMI of 40 kg/m^2 or higher, or BMI range of 35 to 40 kg/m^2 accompanied by severe Type 2 diabetes or cardiovascular risk factors. However, if they do not have any comorbidities despite falling within the BMI range of 35 to 40 kg/m^2, or if their BMI is less than 35 kg/m^2, they are not considered eligible for bariatric procedure (Sjöholm et al., 2013). However, guidelines currently recommend performing bariatric surgery for people with a BMI of 35 kg/m^2 or greater, regardless of the presence, severity, or absence of obesity-related illnesses. Moreover, it was reported that appropriately selected adult and children with a BMI of 30-34.9 kg/m^2 accompanied by diabetes or metabolic syndrome can also undergo bariatric surgery (Eisenberg et al., 2022).

Ethical Approval

This study was conducted in compliance with the ethical principles established by the institutional and/or national research committee, as well as with the 1964 Helsinki declaration and its subsequent revisions, or equivalent ethical standards. The study participants provided informed consent. The Indiana University Institutional Review Board provided ethical approval for this study (Project no:1402503345).

Study Design

The cohort underwent a total of four assessments consisting of a baseline measurement prior to LAGB surgery, followed by follow-up assessments at the clinic at 6 weeks, 12 weeks, and 24 weeks. Anthropometric parameters, including body mass, height, and circumferences of the abdomen, waist, and hips, were measured during each visit. Furthermore, a static balance test, a 10-meter walk test, and a timed get-up-and-go test were conducted during each session. The participants' physical activity levels were evaluated preoperatively and 24-weeks post-surgery via a questionnaire.

Operative Technique: During the surgical procedure, all bands were positioned with the aid of a laparoscope, employing established surgical techniques. Concurrently, hiatal hernias were treated when encountered. A pars flaccida technique was employed as standard practice and routinely performed band fixation was also applied (Ray & Ray, 2011).

Anthropometric Measurements: The anthropometric variables (height, body mass, BMI, waist circumference [WC], waist-to-hip ratio [WHR], were recorded. Height was recorded using a Stadiometer (SECA 213) in a standing position with shoes removed, and weight was determined using Healthometer Pro Plus Electronic Folding Wheelchair Scale Model

2600KL.The Body Mass Index (BMI) is a measurement determined by dividing a person's weight (in kilograms) by the square of their height (in meters squared). According to World Health Organization (2021), BMI classification was evaluated as: underweight (BMI<18.5 kg/m^2), healthy weight (BMI between 18.5 and 24.9 kg/m^2), overweight (BMI between 25 and 29.9 kg/m^2), and different classes of obesity (class I: BMI between 30 and 34.9 kg/m^2, class II: BMI between 35 and 39.9 kg/m^2, and class III: BMI>40 kg/m^2). Waist to hip ratio (WHR) was calculated by dividing WC (cm) by the hip circumference (cm), and it was calculated as a measure of regional fat distribution (Alberti et al., 2005). Subjects were instructed to stand still while the researcher used a standard tape measure to measure around the widest point of the hips and the narrowest point of the waist (in cm). BMI, WC, and WHR were categorized to define the degree of obesity according to international criteria (Alberti et al., 2005). The classifications given by WHO were employed to determine threshold categories for two different parameters: waist circumference (WC) and waist-to-hip ratio (WHR) in females. For WC, a measurement of less than 80 cm was considered predictive of normal weight, while a measurement between 80 cm and 87.9 cm indicated being overweight, and a measurement of 88 cm or greater indicated obesity. As for WHR, a ratio of less than 0.85 was considered normal, while a ratio of 0.85 or greater was indicative of central obesity (Winter et al., 2016).

Evaluation of Habitual Physical Activity: Physical activity was also determined using a questionnaire at pre-surgery and the 24-week follow-up. Subjects were asked to share information regarding the frequency, intensity, duration, and type of activity they engaged in regularly. Most subjects indicated that they engaged in physical activity on a regular basis, and the preferred activity was walking. In general, they engaged in moderate-intensity physical activity for approximately five days per week, amounting to a total of 243 minutes per week.

Static Balance: Balance control was evaluated using a force platform (Accugait System AMTI Balance Platform) which was used to measure the normally occurring oscillations of the body’s postural sway. Subjects stood barefoot on the platform with their feet 10 cm apart. This distance was maintained by marking the platform with tape to ensure standardization of foot placement. Subjects were instructed to stand with arms at sides, and palms toward their thighs. The subjects were asked to stand as still as possible on the force platform for three 90-second trials with eyes open, followed by three 90-second trials with eyes closed. They were allowed to take breaks as needed between trials.

Ten-meter Walk Test: The 10-meter walk test (10mWT) was employed as an assessment tool to analyze the spatial, temporal, and kinematic features of gait. Participants were directed to initiate walking 1.2 meters before the starting line and to continue for 1.2 meters past the finishing line at their habitual pace to mitigate the impact of acceleration and deceleration components. To reduce the learning effect, the subjects underwent three training sessions, and the analysis focused on their best performance. A digital stopwatch was used to record the walking time of all participants, while the number of steps taken during each test was also tallied. The speed measurements obtained from each trial was estimated using these data (Novaes et al., 2013).

Timed up-and-go Test: The Timed Up and Go (TUG) is a fundamental tool to evaluate functional mobility that requires participants to complete a series of movements, including standing up from a chair, walking quickly for 3 meters, crossing a line on the ground, turning around, walking back, and sitting down again. The test was administered twice, and the mean time in seconds taken to complete the test was recorded as the TUG test score (Nording et al., 2008).

Statistical Analysis

The study collected data for each measurement four times, including pre-operation, 6-week, 12-week, and 24-week assessments. Descriptive statistics were used to express the results as medians, first and third quartiles. To test differences between assessments, a Friedman test was performed, and Dunn-Bonferroni post-hoc tests were applied. Statistical significance was determined with a p-value of ≤ 0.05.

RESULTS

Eight subjects participated and completed all data collection sessions. Median, first and third quartile values are summarized in Table 1 and the results from the Freidman tests are summarized in Table 2. Statistically significant differences were found in weight, BMI, waist, hip, waist-hip rate, abdomen, static balance (eyes open), timed up-and-go, 10m walk, and number of steps in 10m. The results are pairwise comparisons of significant variables during 24-week follow-up in Table 3.

Table 1. Changes in anthropometric characteristics, static balance, and functional mobility variables

	Pre-op	*6-week*	*12-week*	*24-week*
Weight (kg)	110.22 (89.36, 113.85)	101.15 (88.45, 110.22)	98.88 (87.09, 110.68)	91.63 (85.73, 110.22)
BMI (kg/m^2)	39.3 (36.48, 42.2)	36.53 (35.39, 41.69)	35.71 (34.84, 41.86)	34.49 (32.27, 41.69)
Waist circumference (cm)	110 (100, 113)	104 (95, 109)	101 (90, 107)	94 (86.69, 115)
Hip circumference (cm)	130 (120, 131.5)	126 (117, 130)	122 (116, 124)	119 (109, 138)
Waist hip ratio (cm)	0.84 (0.81, 0.91)	0.82 (0.8, 0.87)	0.82 (0.78, 0.84)	0.81 (0.79, 0.85)
Abdominal circumference (cm)	123 (109.5, 125)	113 (107, 122)	108 (105, 122)	106 (99, 123)
Static sway eyes open (mm^2)	16.09 (11.97, 22.62)	8.58 (7.55, 14.41)	11.34 (8.87, 12.41)	11.86 (9.96, 17.62)
Static sway eyes closed (mm^2)	33.04 (23.83, 43.12)	26.48 (18.5, 54.52)	20.53 (18.97, 27.02)	24.66 (15.9, 60.47)
Timed up-and-go (s)	8.7 (7.91, 9.23)	8.53 (8.1, 9.47)	7.6 (7.2, 7.83)	7.23 (6.8, 7.58)
10m-Walk (s)	7.47 (7.03, 8.01)	7.4 (6.93, 7.93)	6.81 (6.47, 7.08)	6.5 (6.1, 6.94)
Steps in 10m walk	15 (14, 15)	14.33 (14, 15.33)	14 (13.33, 14.67)	13.33 (13, 15)

Values are median (Q_1, Q_3), Q_1: First quartile, Q_3: Third quartile, (n = 8), BMI= Body Mass Index

Table 2. Statistical Analysis of Differences Between Baseline, 6-Week, 12-Week and 24-Week Values

	n	***χ^2-value***	***df***	***p***
Weight (kg)	8	25.112	3	<0.001**
BMI (kg/m^2)	8	25.112	3	<0.001**
Waist circumference (cm)	8	18.034	3	<0.001*
Hip circumference(cm)	8	10.125	3	0.018*
Waist-hip ratio (cm)	8	8.933	3	0.030*
Abdominal circumference (cm)	8	10.674	3	0.014*
Static sway eyes open (mm^2)	8	8.067	3	0.045*
Static sway eyes closed (mm^2)	8	1.933	3	0.586
Timed up-and-go (s)	8	14.200	3	0.003**
10m walk (s)	8	19.000	3	<0.001**
Steps in 10m walk	8	10.793	3	0.013*

Friedman test: * denotes p ≤ 0.05; ** denotes p ≤ 0.01

Table 3. Pairwise Comparison of Significant Variables During 24-Week Follow-Up

Parameters	***pre vs. 6-week***	***pre vs. 12-week***	***pre vs. 24-week***	***6-week vs. 12-week***	***6-week vs. 24-week***	***12-week vs. 24-week***
	$p^{\ddagger}$	***$p^{\ddagger}$***	***$p^{\ddagger}$***	***$p^{\ddagger}$***	***$p^{\ddagger}$***	***$p^{\ddagger}$***
Weight (kg)	0.331	0.011*	<0.001**	0.999	0.021*	0.497
BMI (kg/m^2)	0.331	0.011*	<0.001**	0.999	0.021*	0.497
WC (cm)	0.602	0.004**	0.001**	0.497	0.215	0.999
HC (cm)	0.215	0.171	0.016*	0.999	0.999	0.999
WHR (cm)	0.999	0.028*	0.215	0.724	0.999	0.999
AC (cm)	0.865	0.037*	0.037*	0.999	0.999	0.999
SSEO (mm^2)	0.037*	0.268	0.865	0.999	0.999	0.999
TUG (s)	0.999	0.106	0.006**	0.407	0.037*	0.999
10m walk (s)	0.999	0.064	0.001**	0.268	0.006**	0.999
Steps in 10m walk	0.999	0.602	0.049*	0.724	0.064	0.999

Multiple comparison adjusted p values were reported; * *denotes p ≤ 0.05;* ** *denotes p ≤ 0.01;* WC: Waist circumference (cm); HC: Hip circumference (cm); WHR: Waist-hip ratio (cm); AC: Abdominal circumference (cm); SSEO: Static sway eyes open (mm^2); TUG: Timed up-and-go (s)

Values for weight, BMI, WC, HC, WHR, AC, SSEO, TUG, 10m walk and steps in 10m walk significantly differed over time (p<0.001), whereas no statistically significant difference was noted in the SSEC value within the study period (p>0.05). Pair-wise comparisons with Bonferroni correction revealed significant change from preoperative values in the postoperative period; for SSEO in the postoperative 6th week, for weight, BMI, WC, WHR and AC in the postoperative 12th week and for weight, BMI, WC, HC, AC, TUG, 10m walk and step in 10 m walk in the postoperative 24th week (p<0.05). In addition, while no significant changes were noted from 6th to 12th week and from 12th to 24th week of postoperative period, the values for weight, BMI, TUG and 10 m walk significantly differed between 6th and 24th postoperative week measurements (p<0.05). After the 24 weeks, the mean body weight (16.87%), BMI (12.24%), waist circumference (14.54%), hip circumference (8.46%), waist hip ratio (3.57%), abdominal circumference (13.82%), static sway eyes open (26.29%), static sway eyes closed (25.36%), timed up-and-go (16.89%), 10m-walk (12.98), steps in 10m walk (11.13%) values were decreased significantly.

DISCUSSION

The main finding of the study was the gradual decrease in body weight and BMI values of participants after the Laparoscopic Adjustable Gastric Banding (LAGB) surgery. This finding seems notable given the association of reduction in body weight particularly with decreased likelihood of comorbidity as well as with an improved general health status among excessively obese patients (Pi-Sunyer, 2002). In the present study obese individuals achieved an average weight loses of 18.59 kg (-16.86 %) during the 6-month period. Moreover, the BMI category of participants improved considerably within the study period, from a mean BMI value consistent with obesity class II (39.3 kg/m^2) preoperatively to those consistent with obesity class I (34.49 kg/m^2) at the end of 24th postoperative week (-12.23 %). There are a variety of protocols and strategies presently employed in bariatric surgery, which result in significant weight loss. However, out of the 7,371 clinical studies evaluated, only 29 studies (0.4%, encompassing 7,971 patients) fulfilled the inclusion criteria and reported long-term outcomes with adequate patient follow-up to reduce the bias. The trials evaluating gastric bypass included six prospective cohorts and five retrospective cohorts, while sleeve gastrectomy studies involved in two retrospective cohorts. The results demonstrated more than 50% excess weight loss with a mean, median, or both that had a 95% confidence interval. On the other hand, extreme weight loss up to this level was detected in only 31% of gastric band studies, consisting of nine prospective cohorts and five retrospective cohorts. After adjusting for the number of participants in each group, the mean percentage of additional weight loss was 65.7% (out of 3544 individuals) for gastric bypass surgery and 45.0% (out of 4109 individuals) for LAGB. Ninety-nine patients were recorded at a one-year follow-up and had an average weight loss of 44.3% excess body weight with LAGB (Puzziferri et al., 2014). O'Brien et al., (2006) conducted a study to evaluate the safety and efficacy of LAGB in treating obesity and found weight loss greater than 50% for up to 6 years. In a study by Ray & Ray (2011), the 60-month follow up of 442 patients (77% were females) after LAGB revealed excess weight loss of 27% at 6-months, 38% at 12-months, 44% at 18-months and 60% at 60-months after surgery. In the current study, overall weight loss (-16.86 %) achieved among 8 patients at the end of the 24th week was lower than reported by Ray & Ray (-27%). This discrepancy in weight reduction outcome may be related to the considerable difference in sample sizes of the two studies as well as inclusion of females in the current study.

Recent studies suggest that measures of abdominal obesity are increasingly linked to a higher risk of cardiometabolic diseases in both cross-sectional and prospective studies, however BMI has been used as an indicator for obesity for many years. The between individual variation in total body fat is not completely captured by BMI, which represents the relationship between weight and height (Kwan et al., 2014). The lack of data on body fat and muscle percentage distribution via body composition analysis is an important limitation of the current study. However, the measurement of fat distribution known as WHR is indicative of both adipose tissue and muscle mass. Similarly, a decrease in body weight may be associated with a relative increase or decrease in the muscle strength. Nonetheless, given that strength assessment was not performed in the current study, it is not possible to draw conclusions based on our findings, emphasizing the need for future studies addressing this subject.

Our findings at the end of the 24th postoperative week revealed a 16 cm decrease (14.54%) in waist circumference of patients in parallel to 17 cm decrease (13.82%), noted in the abdominal region. In addition, significant reductions obtained in waist and abdominal circumference were more pronounced within the first 6 postoperative weeks and remained to be significant for the 12 weeks after the operation. However, identification of no further improvement in both parameters after the 12th week seems to indicate rapid initial body adaptation to the new postoperative status that reaches a plateau. It should also be noted that in our patients, waist circumference values were higher than the central obesity criteria (WC >88 cm) defined by the World Health Organization (Winter et al., 2016) preoperatively, and were still within the range of central obesity even after the 24th week, despite significant reductions in waist and abdominal circumference.

Overweight individual's ability to maintain proper posture may be reduce as demonstrated by changes in postural sway and delayed motor reaction time (Emara et al., 2020). In a study by Reyder et al., (2016) among 242 adolescents (59 boys, 183 girls, mean±age: 17±2 years, BMI: 53±9 kg/m^2) with severe obesity, functional mobility was assessed via a 400 m walk test in the preoperative and postoperative (6, 12 and 24 weeks) periods after three different surgery methods including Roux-en-Y gastric bypass (RYGB) (n=161), sleeve gastrectomy (SG) (n=67) and laparoscopic adjustable gastric banding (LAGB) (n=14). The authors noted considerable recovery of functional mobility to start from the postoperative 6th month and this recovery continued until the 12th and 24th months of operation. The authors have deduced that bariatric surgery is linked to a marked improvement in functional mobility among adolescents who suffer from severe obesity. In addition, the surgery was found to be linked to a reduction in musculoskeletal pain triggered by walking, which can persist for up to 2 years after the surgery (Ryder et al., 2016). Likewise, in a 3-year longitudinal follow up study among 2458 male and female participants (age: 47years; BMI: 45.9 kg/m^2; 70,4% underwent RYGB; 25 % underwent LAGB) by King et al. (2016), 400 m walk test revealed clinically relevant improvements in physical functional capacity by 76.5% and in walk time by 59.5% at the end of the first year, whereas the improvement decreased within 1-3 years. In the current study, while no significant change was noted in functional mobility parameters including time up go and 10-meter walk tests within the first 6 weeks of surgery, the improvement achieved at the 24th post-operative week is in line with findings reported by Reyder et al., (2016). This seems to support the improvement in functional mobility among bariatric surgery patients in the long-term postoperatively, regardless of the type of operation, the patient age and gender. In addition, improvement in walking economy was also noted in our patients who achieved faster walking time by taking fewer steps in a shorter amount of time.

There are studies in the literature regarding body composition changes after surgical interventions using different methods in obese individuals. However, no studies to date have investigated the impact of weight-loss obtained via surgery on balance and functional mobility in these individuals, which rules out the possibility of comparing our results with the findings from similar studies.

The postural control of obese and morbidly obese males improved after the weight loss (Pereira et al., 2017). There is a significant correlation between higher body weight and decreased ability to maintain a stable posture (Lee et al., 2020). A study reported that weight loss led to an improvement in balance control, as measured by the speed of the center-of-foot pressure. On average, the obese group experienced a 0.10 cm/s (12% increase) improvement, while the excessively obese group had a 0.28 cm/s (27% increase) improvement. Data refuted the obvious argument that increased relative strength improved balance control, as balance control improved despite a lack of improved relative force according to data obtained pre-surgery vs post-surgery for obese individuals and pre-surgery vs 3 months post-surgery for excessively obese individuals. According to the study findings, weight loss appears to be a more effective strategy for enhancing balance control compared to increasing or maintaining muscle strength (Handrigan et al., 2010).

It has been observed that people who are obese tend to have greater postural sway compared to those who have a healthy weight. This indicates lower stability and consequently, weaker balance. This would further imply that perturbations would produce a greater response in obese individuals, increasing the difficulty of maintaining balance (Jadelis et al., 2001). Known to be multifactorial, falls are not always caused by stumbling or slipping. The non-permanent parameters of a stabilizing response are remarkable, e.g., the delay in onset of a counteracting torque and the velocity of torque formation are considered critical factors for stabilizing responses. However, the effect of weight loss on these factors has not been fully elucidated (Simoneau & Corbeil, 2005). In a study conducted on 102 overweight and obese women, it was concluded that obesity increases the oscillation rate in eyes open and eyes closed, negatively affecting postural stability (Rezaeipour, 2018). A greater number of falls were reported by those who were extremely obese (BMI > 40 kg/m^2); however, there was lower sample size of participants in the extremely obese group (3.5%) compared to other BMI categories (Beck et al., 2009).

The differences of surgical methods can affect the results and cause considerable discrepancy in evaluating the data. It can be argued that the improved balance control subsequent to weight loss results from improved relative muscle strength. In other words, muscle strength is essential to maintain balance control in overweight and obese individuals. In obese individuals undergoing bariatric surgery, exercises increasing muscle strength may be recommended in the postoperative rapid weight loss period as a means to improve balance control and functional mobility of these individuals.

Conclusion

At 24-month follow-up following the LAGB operation, weight loss, reduction in waist circumference, increase in the walking speed and the number of steps taken per time, and improvement in functional mobility were clearly demonstrated. In addition, the reduction in surface oscillations during static balance indicated improved postural balance performance over time. However, further support of our preliminary results obtained from a single surgical method requires studies with larger samples using diverse bariatric surgical approaches.

Authors' Contributions

MKY: conceived of the study, study design, conduct of the data collection, manuscript preparation, manuscript editing, SR: study design, supervisor of the study, HET: manuscript preparation, manuscript editing, DMK: data analysis, statistical analysis and manuscript editing, KK: data analysis, statistical analysis, JBR: surgeon, WR: data collection. All authors have read and approved the final version of the manuscript.

Author Disclosure Statement

No competing financial interests exist.

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Ethics Committee Approval

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