Changes in physical activity behaviour and physical function after bariatric surgery: a systematic review and meta-analysis

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(8) **Abbreviations:** PA, physical activity; PF, physical function; BMI, body mass index; SD, standard deviation; SE, standard error; CI, confidence interval; SPPB, short physical performance battery; SF-36, short form health survey; SMD, standardised mean difference.

Abstract

Although physical activity performed after bariatric surgery is associated with enhanced weight loss outcomes, there is limited information on patients' physical activity behaviour in this context. This systematic review and meta-analysis assessed pre to post-operative changes in physical activity and physical function outcomes among obese adults undergoing bariatric surgery. A total of 50 studies met inclusion criteria with 26 papers reporting data for meta-analysis. Increases in both objectively recorded and self-reported physical activity at 12 months were demonstrated. Studies indicated that there was a shift towards a greater amount of active time, but of a lower intensity within the first 6 months of bariatric surgery, suggested by a reduction in moderate to vigorous physical activity but an increase in step count. A standardised mean difference (SMD) of 1.53 (95% CI: 1.02 to 2.04) based on nine studies indicated improved walking performance at 12 months. Similarly analysis of five studies demonstrated increased musculoskeletal function at 3-6 months (SMD: 1.51; 95% CI: 0.60 to 2.42). No relationship was identified between changes in weight and walking performance post-surgery. More studies assessing physical activity, physical function, and weight loss would help understand the role of physical activity in optimising post-operative weight and functional outcomes.

Introduction

Bariatric surgery is an effective weight-loss intervention for morbidly obese patients, and also a successful treatment for comorbidities such as type 2 diabetes mellitus[1]. A higher level of physical activity after surgery has been associated with additional weight loss[2-4]. There is currently limited information on patterns of physical activity in bariatric surgery patients. One review suggested that physical activity tended to increase after surgery, although considerable variation in results was observed[4]. This was partly attributed to the heterogeneity in measurement tools across the studies included, most of which relied on self-reported methods for assessing physical activity. It is notable that more recent studies[5-7] have included objective methods which may provide more accurate estimates of changes in physical activity.

In addition to weight loss, several studies have reported positive changes in physical function outcomes after surgery, such as cardiovascular endurance and muscular fitness[5, 8-10].

These functional abilities are important for enabling individuals to carry out activities of daily living such as housework, childcare, lifting and carrying heavy objects, walking up hills or stairs. A recent narrative review suggested that physical function improves after bariatric surgery[11], but it remains unclear whether the improvements are a direct consequence of weight loss, or whether physical activity leads to superior outcomes, over and above the weight loss associated with surgery.

Given the rapidly-growing literature in physical activity for bariatric surgery patients, a comprehensive and up-to-date review of the evidence is due. This review, therefore, aims to assess pre to post-operative changes in physical activity behaviour and physical function outcomes among obese adults receiving bariatric surgery.

Methods

Eligibility criteria

Studies were included if they involved at least 10 adults (aged ≥18 years) undergoing weight-loss surgery, reported prospective assessments of physical activity or physical function pre-surgery and at three or more months post-surgery. Published and unpublished studies were searched and no language restrictions were imposed. Physical activity measures included self-reported and objective methods (e.g. accelerometer, pedometer). Measures of physical function included tests of cardiovascular endurance (e.g. treadmill/cycle ergometer stress tests, timed walking tests), musculoskeletal fitness (e.g. timed up-and go, 1-rep repetition maximum tests) and self-report (e.g. physical functioning scale of the Short-Form Health Survey; SF-36). Studies were excluded if they only reported measurements at one time point (i.e. only pre-surgery or only post-surgery), or only assessed anthropometric outcomes, gait biomechanics, cardiac or respiratory muscle function.

Search methods

The search strategy was developed for Medline with advice from an information specialist. The following electronic databases were searched from their respective inceptions: Medline, SPORTDiscus, Cinahl, EMBASE, Cochrane Library, SCIRUS and OpenGrey (an unpublished literature source). Search terms included MeSH headings and key words based on bariatric surgery (e.g. bariatric surgery, gastric bypass, gastric band), physical activity/ physical function (e.g. exercise, physical activity, physical fitness, muscle strength) and were modified for each individual database. In addition to searching databases, the reference lists of all included papers and relevant review articles were scanned for further eligible studies[12]. The citation tracking service within Web of Science was also used for all papers meeting the review criteria in order to identify papers published subsequently that may be eligible for

inclusion. Finally, five experts in the field of exercise and obesity were contacted to ask for any further published or unpublished studies. Studies were included up until July 2015.

Study selection

The titles and abstracts of all items identified through the electronic searches were screened for potential eligibility by the primary author (LH) and a random 25% of items were screened independently by a second reviewer (CS) to check for consistency. A kappa score of 0.93 was achieved. Full versions were read by two reviewers (100% by the primary author [LH] and 50% each by two further reviewers [CS, PC]) who independently applied the selection criteria and recorded the decisions on a standardised form. The three reviewers met to discuss any disagreements to reach a consensus.

Data extraction

A data extraction form was developed and piloted. Details on study design, participants, outcome measures, and results were recorded. The primary researcher (LH) reviewed and extracted 100% of the data and two reviewers independently reviewed and extracted 50% each (CS, PC). Any disagreements regarding data extraction were discussed until consensus reached. In eight cases study authors were contacted in an attempt to obtain any missing information.

Data analysis

All included studies were summarised descriptively in tables. Meta-analyses were conducted using Review Manager version 5.3 for Windows, for outcomes where mean and standard deviation (SD) data were available, or could be obtained, from at least four studies. Post-surgery assessments mostly aligned with one of two time points: 3-6 months, and 12 months. To allow for the use of different measures across studies for some outcomes, pre-post changes were calculated as a standardised mean difference (SMD) using Hedges' (adjusted) g,

which includes a correction for sample size bias. Studies were combined using a random-effects model. Statistical heterogeneity was assessed by the I^2 test[13].

Results

Study characteristics

After removing duplicates, 990 articles had been identified by the search; 50 studies met the inclusion criteria for the review and 26 papers reported data to be included in the meta-analysis (Figure 1). The majority of studies were performed in the United States [5, 7, 14-32], with five conducted in the Netherlands[33-37] and four in Brazil[9, 38-40]. The types of bariatric surgery received by participants varied between studies, but the two main surgery types were Roux-en-y gastric bypass (29 studies)[9, 14, 16-25, 27, 29-32, 34, 38-48] and gastric banding (8 studies)[33, 35-37, 49-52]. Fourteen studies reported a physical activity outcome [7, 14, 15, 17, 23, 25, 35-37, 41, 42, 46, 53, 54], 30 reported a physical function outcome [8-10, 18-21, 24, 26-34, 38-40, 43, 44, 48, 50-52, 55-58]and six reported both physical function and physical activity data [5, 16, 22, 45, 47, 49]. Included studies are described in Tables 1 (physical activity outcomes) and 2 (physical function outcomes).

Physical activity outcomes

Seventeen studies employed self-reported measures of physical activity, with seven reporting increased activity at 3-6 months, and 11 at 12 months (Table 1). All but one study[17] reported improvements in activity 12 months post-surgery. Two studies reported leisure time physical activity at both time points. Sjostrom *et al*[54] reported from a study of 1845 participants that the proportion of individuals classified as active increased by 37.3% at 3-6 months, which was maintained at 12 months. Vatier *et al*[46] reported an improvement in leisure time physical activity of 10 minutes per week at 3-6 months, and a further improvement of eight minutes per week at 12 months. Seven studies used objective measures of physical activity (five used accelerometers and two used pedometers). Step count data indicated an average increase of

between 1225-2749 daily steps[5, 22, 49], but accelerometer results suggested little change at either 3-6 months or 12 months[7, 15, 23, 41].

Physical function outcomes

All studies assessing cardiovascular endurance outcomes reported improvements post-surgery (Table 2). These included 20 tests of walking performance (treadmill exercise test, fastest possible walking speed, walking speed, walking minutes per week, 6 minute walk test (6 MWT), 4-metre walk time, walking energy expenditure) [9, 16, 22, 24, 26-31, 34, 38-40, 45, 47, 50, 51, 56, 57]and two of cycle ergometer endurance[55, 58]. Meta-analysis based on 11 studies showed an increase in walking performance at 3-6 months (SMD: 0.82; 95% CI: 0.57 to 1.06), with a heterogeneity score of I^2 =43% (Figure 2). At 12 months, analysis of nine studies also indicated increased performance (SMD: 1.53; 95% CI: 1.02 to 2.04: I^2 =83%) (Figure 3). Sub-sample analyses were carried out on the 6 MWT, a test indicative of functional exercise capacity. At 3-6 months, based on five studies, an increase of 74.55 metres (95% CI: 46.9 to 102.2) was shown, with a heterogeneity score of 59%. From the three studies reporting 12 month data the increase was 184.36 metres (95% CI: 1.35 to 2.30). There was no clear association between percentage weight change and percentage change in walking performance pre to 12 months post bariatric surgery (Figure 4).

Measures of musculoskeletal function were used in 10 studies. Table 2 displays the specific tests and indicates the direction of results. Meta-analysis demonstrated improvements 3-6 months post-surgery with a SMD of 1.51 (95% CI: 0.60 to 2.42; I^2 = 81%). Only two studies examined musculoskeletal outcomes at 12 months with both showing improved outcomes[21, 24]. Measures of absolute muscle strength/force/torque were reported in five studies with post-surgery assessment ranging from 3 to 12 months. All studies reported a reduction in absolute

strength post-surgery, with pooled data indicating a SMD of -1.04 (95% CI: -1.76 to -0.33), and heterogeneity score of I^2 =77%.

Eighteen studies included self-reported physical function, 17 of which used the SF-36 [5, 16, 18-22, 32, 33, 43-45, 49, 52, 57] for assessing physical function. All studies reported an increase in the physical function or physical component score post-surgery (Table 2). Mean SF-36 scores are recorded out of a maximum of 100. Meta-analysis of eight studies indicated a mean SF-36 score difference of 22.57 (95% CI: 14.92 to 30.21) and heterogeneity score of I^2 = 91% at 3-6 months. At 12 months, the mean SF-36 score difference from eight studies was 22.35 (95% CI: 16.6 to 28.10, I^2 = 95%).

Discussion

This review indicates that physical activity is increased after bariatric surgery, as assessed by self-reported and objective measures. All cardiovascular and musculoskeletal measurements of physical function improved from pre to post surgery, while absolute muscle strength measurements decreased. Meta-analyses of physical function suggest that self-reported physical function (SF-36), objective musculoskeletal, and walking function improved within 6 months of bariatric surgery and improved further by 12 months post-surgery.

Physical Activity

Self-reported outcome measures consistently indicated increased physical activity post-surgery. However, the heterogeneity of measurement tools makes comparisons between studies difficult. The Leisure Time Physical Activity Questionnaire [59] was used in 3 studies, but a further 12 other tools were reported across the remaining 14 studies. These provide a range of outcome data based on minutes of activity[15-17, 22, 42, 46, 47], energy expenditure[14], points on a scale[35, 36, 45], questionnaire specific scoring[37, 49] or percentage of active participants[25, 53, 54]. Consistent use of a validated assessment tool across studies would allow meaningful comparisons of physical activity behaviour in this population.

When examined by length of follow up, self-reported physical activity increased after surgery in all studies at 3-6 months, and in all except one study at 12 months. However, whether self-reported measures of physical activity concur with objectively measured physical activity in this population has been questioned[15].

In the current review, accelerometers and pedometers were utilised to obtain objective measurements in seven studies. Only one of three studies demonstrated an increase in physical activity based on step count from pre to 3-6 month follow up[22], whereas all four studies showed increases at 12 months. The two studies indicating a decrease in physical activity at 3-6 months post-surgery were based on accelerometer data collected at exactly 6 months[15, 23]. However the type of physical activity differed (total physical activity[23] versus moderate to vigorous physical activity (MVPA)[15]). This reduction in physical activity could be a result of the post-surgical metabolic changes induced by calorific restriction[23]. The study reporting increased physical activity 3-6 months post-surgery found an increase of 2749 steps per day[22]. Step count does not provide an indication of the intensity of the activity undertaken; however, when taking in to consideration the reduction of MVPA and total physical activity, an increase in step count would suggest a shift in the intensity of physical activity being undertaken 3-6 months post operatively. Participants may therefore undertake more light activity at earlier post-operative time points.

The improvement in self-reported physical activity from pre to 3-6 months, and the general reduction in objectively measured physical activity using accelerometers at the same post-operative time point is of interest. Results support previous research which has also demonstrated over-reporting of post-operative physical activity[15]. Over-reporting may represent a change in perceptions in the ease of performing activities, due to improved physical function resulting from weight loss. Further research is therefore needed to determine the reason for over-reporting post-operative physical activity in this population. This over-reporting of physical activity, if unintentional, could have a detrimental outcome on long-term weight maintenance. This review does, none the less, indicate that from pre to 12 months post-bariatric surgery both objective and self-reported physical activity increases.

Only two studies measured physical activity at both 3-6 months and 12 months post-surgery, both of which used self-reported tools[46, 54].Sjostrom *et al*[55] reported that the proportion of individuals that were self-categorised as active increased by 37% at 3-6 months and was maintained at 12 months after surgery, although we cannot tell their volume of physical activity. Vatier *et al*[47] reported an improvement in leisure time physical activity at both post-operative time points. Physical activity increased more in the first 3-6 months after bariatric surgery and then continued to improve at 12 months but at a slower rate, reflecting weight loss patterns observed in previous research[54]. Weight loss after bariatric surgery occurs rapidly in the first 6 months and slows towards 12 months with weight regain indicated at the 12 to 24 month time point[54].

The most recent study included in this review focused on objective MVPA assessed by accelerometry in a large sample. It suggested that 89.4% of post-surgery patients were still not sufficiently active by 12 months post-surgery[5], that is they were not meeting the guidelines of ≥150 minutes of moderate intensity physical activity weekly as recommended for the general adult population[60]. Step count data indicated that participants were classified as 'somewhat active'; that is, likely to be undertaking some volitional activities and/or occupational activity 12 months post-surgery[61]. Self-reported physical activity questionnaires predominantly focus on leisure time physical activity, making it difficult to determine intensity and enable comparisons to current physical activity guidelines. A large study by Colles *et al*[49] did however differentiate between physical activity domains showing leisure time and sport physical activity increased whereas work physical activity remained the same 12 months post-operatively. The variability of self-reported and objectively measured physical activity tools used in the different studies within this review makes it difficult to definitively state that physical activity guidelines are not met 12 months post-surgery. More research is therefore needed to determine if the increase in physical activity is sufficient. If not, interventions for increasing physical activity to recommended levels post-surgery should be explored.

Objective Physical Function

Extreme obesity drastically inhibits physical function, physical performance and increases disability[24]. The current meta-analyses displayed large improvements in walking outcomes at 3-6 months and even greater improvements at 12 months through bariatric surgery. As previously reported, walking speed slows as a result of obesity[45]. Therefore any post-operative improvements in walking speed would be likely attributed to weight loss which would mean the greatest improvements occurring within 6 months of surgery. Walking distance improvement appeared to be similar between post-surgery segments (pre to 3-6 months, 3-6 to 12 months) and functional walking distance patterns increased consistently to 12 months at a greater rate than either physical activity or weight loss. This suggests that walking improves as a result of weight loss, although it seems likely that physical activity is required for improvement to be maintained once the rate of weight loss plateaus. However, the 12 month pooled result should be interpreted with caution due to high heterogeneity.

Objective evaluation of fitness and functional exercise capacity in this population is regularly assessed by the 6 minute walk test[9]. The mean improvements in all the studies which reported the 6 minute walk tests distance from pre to 3-6 months and pre to 12 months post-surgery were 75 metres and 184 metres respectively. A minimal clinically importance difference (MCID) for the 6 minute walk test in bariatric surgery patients has not been established. However, for patients with chronic obstructive pulmonary disease, a change in the range of 54 to 80 metres has been estimated as clinically meaningful[62]. Based on these data, the improvement of 184 metres observed at 12 months in this analysis, is likely to be of sufficient magnitude to be clinically useful in this population.

Large increases in musculoskeletal function were recorded at 3-6 months, which can translate into mobility and strength improvements that facilitate activities of daily living. These might include housework, stair climbing, hill walking, lifting and carrying heavy objects[11, 24, 47]. Previous research has also found that obesity affects musculoskeletal function and movements of daily living such as transitioning from sitting to standing[24,45]. The small number of studies reporting 12 month outcomes meant meta-analysis was not possible. The two studies which did report 12 month data also reported 3-6 month data helping the understanding of post-surgery musculoskeletal function patterns. One study reported the timed ‘get up and go’ test which improved by 2.3 seconds by 3-6 months, and a

further 0.7 seconds at 12 months[21]. This improvement is more than double the minimal detectable change of 1.14 seconds reported in the literature[63]. The second study reported the short physical performance battery score improvement of 1.2 points at 3-6 months and a further 0.8 points at 12 months[24]; this is double the score of 1.0 which represents a substantial meaningful change[64]. Both studies show the majority of improvement occurs by 3-6 months concurring with previous research[21]. The current review does show that musculoskeletal function continues to improve at least up until 12 months post bariatric surgery.

With rapid weight loss, drastic fat free mass loss also occurs, typically between 33% and 50% [47,65].This supports the large reduction in absolute muscle strength indicated by the meta-analysis (SMD of -1.04). Muscle torque was the only absolute value reported at both post-operative time points showing a decrease of 15 newton metres by 3-6 months, and a twofold decrease by 12 months. Fat-free mass loss negatively affects resting metabolic rate, with this metabolic response occurring naturally to counter weight loss[66]. Exercise training post bariatric surgery would be a useful intervention to optimise post-surgical weight loss and body composition outcomes[11, 67].

Self-reported Physical Function

All included studies reported improvements in self-reported physical function regardless of post-operative follow up time frame. This suggests patients perceive an improvement in their day to day lifestyle activities and mobility after bariatric surgery. Studies reporting data from both post-operative time points reveal greater improvements in self-reported physical function by 3-6 months after surgery, with smaller improvements or maintenance from 3-6 to 12 months[18, 21, 57]. This suggests that the weight loss is directly responsible for functional improvements. However, it also reflects the patterns observed of post-operative physical activity although data assessing both post-operative time points is currently limited[46]. Minimal clinically important points scores (MCIPS) for the SF-36 have been identified between 10 (small) and 30 (large) in patients with chronic obstructive pulmonary disease[68]. The improvement of 18 points demonstrated at 12 months in the current analysis could therefore be tentatively interpreted as moderately important changes in perceived function.

Objective vs Self-reported Physical Function

Objective and self-reported physical function measurements are not easily comparable because they do not assess the same outcome. Nevertheless when examining the post-operative improvements, physical function as assessed by the SF-36 as a component of health-related quality of life showed a similar mean improvement at both 3-6 and 12 months, whereas the objective measurement of the 6MWT more than doubled in improvement from 3-6 to 12 months. Objective musculoskeletal results also display larger improvements by 3-6 months with continued improvement by 12 months, albeit at a slower rate. Absolute muscle torque was the only absolute value reported at both post-operative time frames showing absolute muscle torque decreased consistently to 12 months. No obvious pattern was shown between objective and subjective methods. This may suggest that self-reported assessments of physical function may over estimate improvements 3-6 months post-surgery, or under estimate improvements 12 months post-surgery, indicating the importance of objective measurement of physical function.

Physical function and weight loss

Positive changes in physical function outcomes and weight loss alone have been reported following bariatric surgery[5, 8-10].We therefore plotted the results of eight studies that provided data on the 6MWT and weight (Figure 4), concluding that the relationship between weight loss and walking performance is still unclear. Research also suggests that physical activity is associated with greater weight loss leading to improved physical function[11], however self-reported improvements in physical function from pre to post surgery as a result of weight loss alone have also been reported[69]. A clear relationship between physical activity, physical function and weight loss is yet to be identified, since patterns have not been directly investigated. Objective physical activity, self-reported physical function and weight have been investigated in two studies[5, 49]. Similarly only two studies report objective physical function, self-reported physical activity and weight[45, 47] and only one study reports weight with both objective activity and function[22]. This makes it difficult to draw conclusions about the relationship between post-operative outcomes, and more studies are needed that assess physical activity, physical function

and weight loss so that post-operative activity guidelines can be developed to optimise individuals' outcomes.

One way to examine the importance of physical activity after surgery for optimising physical function and weight outcomes is through exercise interventions. Although few such clinical trials exist, there are encouraging findings in respect of the benefits of post-surgical exercise. Results of three randomised trials indicate that an additional aerobic exercise programme after gastric banding surgery led to superior improvements in functional capacity over surgery alone[6, 70, 71] (as assessed by the 6MWT). A further trial investigated the effects of resistance training on fitness and functional strength after bariatric surgery, and reported improvements in the sit-to-stand test, $V\dot{O}_2$ max and functional strength compared to non-exercising counterparts[72]. This research therefore suggests the importance of exercise training post bariatric surgery to optimise physical activity, physical function , fat mass loss and preserve fat free mass.

In conclusion, a systematic review of the evidence demonstrates that objective and self-reported physical activity improves by 12 months after bariatric surgery. A decrease in objectively measured MVPA and an increase in step count at 3-6 months, indicates a shift towards a greater amount of lower intensity physical activity within the first 6 months after surgery. Walking, musculoskeletal and self-reported physical function all improved by 12 months. No relationship was identified between changes in weight and physical function. However, based on promising results from pilot studies, larger trials are necessary to further understand the effects of physical activity on post-surgical outcomes.

Figure 1: The systematic review search process.

Table 1: Characteristics of all included studies with pre and post-operative measures of physical activity.

Table 2: Characteristics of all included studies with pre and post-operative measures of physical function.

Figure 2: Meta-analyses of pre to post-operative walking ability at 3-6 months. Forest plots of random-effects meta-analyses of pre to post-operative objective functional walking ability.

Figure 3: Meta-analyses of pre to post-operative walking ability at 12 months. Forest plots of random-effects meta-analyses of pre to post-operative objective functional walking ability.

Figure 4: Percentage improvement in pre to 12 months post-operative walking verses weight.

Table 1: Characteristics of all included studies with pre and post-operative measures of physical activity

Author, publication date (Reference)	Sample size	BMI	Surgery type	Measure of physical activity	Measurement units	Physical activity level Pre-surgery	Physical activity level 3-6 month post-surgery	Physical activity level 12 month post-surgery	Improved outcome when compared to baseline
Self-Reported Physical Activity									
Boan *et al*., 2004[14]	40	52.9	RYGB	Baseline questionnaire of activity	Kcal/week	239.8 ± 266	1230.3 ± 1092	N/A	Yes (990.5 Kcal/week)
Bond *et al*., 2008[16]	119	49.9	RYGB	International PA questionnaire – short form	min/week	170.2 ± 325.2	N/A	385.9 ± 458	Yes (215.7 min/week)
Bond *et al*., 2010[15]	20	50.1	RYGB, GB	Paffenbarger PA questionnaire	min/week	44.6 ± 80.8	212.3 ± 212.4	N/A	Yes (167.7 min/week)
Carrasco *et al*., 2007[42]	31	44	RYGB	Leisure time PA questionnaire	min/week	600 ± 878.4	1410 ± 1374	N/A	Yes (810 min/week)
Colles *et al*., 2008[49]	129	44.3	GB	Baecke PA questionnaire	Baecke total score	6.3 ± 1.17	N/A	7.32 ± 1.27	Yes (1.02Baecke total score)
Das *et al*., 2003[17]	30	50.1	RYGB	Minnesota leisure time PA questionnaire	min/week	2205 ± 1540	N/A	1869 ± 91.7	No (336 min/week)
Josbeno *et al*., 2013[22]	18	46.9	RYGB	7 day PA recall	min/week	191.1 ± 228.23	231.7 ± 239.04	N/A	Yes (40.6 min/week)
King *et al*., 2012[5]	276	47	All	7 day PA diary (≥150 min/week)	Number of people	82 ± 29.7	N/A	127 ± 46	Yes (45 people)
Lyytinen *et al*., 2013[45]	16	45.1	RYGB	Leisure time PA scale	Point scale (1[low]-3 [high])	1.81 ± 0.66	2.0 ± 0.57	N/A	Yes (0.19 point scale)
Mathus-Vliegen *et al*., 2007[36]	44	50.7	GB	PA duration per week	Point scale (1[low]-5 [high] min categories)	2.2 ± 1.0	N/A	2.8± 1.0	Yes (0.6 point scale)
Mathus-Vliegen *et al*., 2004[35]	49	50.0	GB	PA scale Score	Point scale	5.5 ± 1.4	N/A	7.2 ± 2.3	Yes (1.7 point scale)
Rosenberger *et al*., 2010[25]	131	51.8	RYGB	Proportion of people reporting no PA	%	37.4	N/A	7.6	Yes (29.8%)
Ruiz-Tovar *et al*., 2013[53]	50	50.4	SG	Modifiable PA questionnaire	% of sample (sedentary, moderate & active)	45 (90%) sedentary; 4 (8%) moderate; 1 (2%) active	N/A	20 (40%) sedentary; 25 (50%) moderate; 5 (10%) active	Yes (42% moderately active, 8% active)
Sjostrom *et al*., 2004[54]	1845	41.9	GB, RYGB, VBG	Proportion active during leisure time	%	54.7 (95% CI)	92.0 (95% CI)	92.0 (95% CI)	Yes (37.3%); Yes (37.3%)
Vatier *et al*., 2012[46]	86	48.1	RYGB	Leisure time PA questionnaire	min/week	80.0 ± 80.0	90 ± 80	108 ± 84	Yes (10); Yes (18 min/week)
Wouters *et al*., 2010[37]	42	47.0	GB	Baecke PA questionnaire	Sport index score	2.0 ± 0.6	N/A	2.5 ± 0.7	Yes (0.5 sport index score)
Wiklund *et al*., 2014[47]	29	42.0	RYGB	International PA questionnaire – short form	MET min/week	1231 ± 2001	N/A	2428 ± 2979	Yes (1197 MET min/week)
Objective Physical Activity									
Berglind *et al*., 2014[41]	56	39.1	RYGB	Accelerometer	MVPA min/day	30.9 ± 17.7	N/A	32.1 ± 24	Yes (1.2 min/day)
Bond *et al*., 2010[15]	20	50.1	RYGB, GB	Accelerometer	MVPA min/week	41.3 ± 109.3	39.8 ± 71.3	N/A	No (1.5 min/week)
Colles *et al*., 2008[49]	129	44.3	GB	Pedometer	steps/day	6061.0 ± 2740.0	N/A	8716.0 ± 5348.0	Yes (2655 steps/day)
Josbeno *et al*., 2010[22]	11	46.9	RYGB	Pedometer	steps/day	4621.0 ± 3701.2	7370.0 ± 4240.0	N/A	Yes (2749 steps/day)
King *et al*., 2012[5]	310	47.0	All	StepWatch 3	steps/day	7563 (median)	N/A	8788 (median)	Yes (1225 steps/day)
King *et al*., 2015[7]	473	45.4	All	StepWatch 3	MVPA min/week	77.3 (median) (70.9-84.2)	N/A	106.0 (median) (97.8-116.4)	Yes (28.7 min/week)
Liu *et al*., 2012[23]	18	44.6	RYGB	Accelerometer	All PA hours/day	11.1 ± 4.2	10.6 ± 2.5	N/A	No (0.5 hours/day)

KEY: *RYGB: Roux-en Y gastric bypass; GB: gastric banding; VBG: vertical banded gastrectomy; PA: physical activity; min: minutes; Kcal: kilocalories; N/A - not applicable; CI: confidence interval.

Table 2: Characteristics of all included studies with pre and post-operative measures of physical function

Author, publication date (Reference)	Sample size	BMI	Surgery type	Measure of physical function	Measurement units	Physical function level Pre-surgery	Physical function level 3-6 month post-surgery	Physical function level 12 months post-surgery	Improved outcome when compared to baseline
Self-Reported Physical Function									
Bond *et al*., 2008[16]	119	49.9	RYGB	SF – 36	Physical function score	35.2 ± 10.6	N/A	51.9 ± 8.4	Yes (16.7 score)
Colles *et al*., 2008[49]	129	44.3	GB	SF – 36	Physical component score	37.2 ± 10.0	Not stated	49.2 ± 9.8	Yes (12 score)
Frezza *et al*., 2007[18]	40	46.55 (median)	RYGB	SF – 36	Physical function score	17 (range, 10-38)	26.5 (range 11-30)	26.5 (range 11-30)	Yes (9.5 score)
Gorin *et al*., 2009[19]	196	47.2	RYGB	SF - 36	Physical function score	46.5	79.5	N/A	Yes (33.2 score)
Hooper *et al*., 2007[20]	48	51.0	RYGB	SF - 36	Physical function score	38 ± 19	N/A	74.0 ± 21.4	Yes (36 score)
Horchner *et al*., 1999[33]	39	40.9	GB	SF - 36	Physical function score	72.7 ± 23.2	N/A	90 ± 14.3	Yes (17.3 score)
Huang *et al*., 2011[43]	40	43.6	RYGB	SF – 36	Physical function score	57.3 ± 25.9	73.8 ± 22.6	N/A	Yes (16.5 score)
Iossi *et al*., 2013[21]	39	49.0	RYGB	SF – 36	Physical component score	30.1 ± 9.1	40.9 ± 9.5	45.9 ± 11.4	Yes (10.8); Yes (15.8 score)
Julia *et al*., 2013[44]	71	47.6	RYGB	SF-36	Physical function score	38.9	49.9(mean change)	52.6 (mean change)	Yes (49.9); Yes (52.6 score)
Josbeno *et al*., 2010[22]	17	46.9	RYGB	Medical outcomes SF-36	Physical function score	38.2 ± 23.6	89.7 ± 15.5	N/A	Yes (51.5 score)
King *et al*., 2012[5]	310	47.0	All	SF – 36	Physical function score	37.6 ± 10.7	N/A	50.7 ± 8.3	Yes (13.1 score)
Lyytinen *et al*., 2013[45]	16	44.0	RYGB	RAND – 36	Physical function score	58.5 ± 18	81.5 ± 25.6	N/A	Yes (23.0 score)
Nickel *et al*., 2005[52]	21	47.4	GB	SF – 36	Physical function score	37.8 ± 13.1	N/A	61.3 ± 17.2 (3 years)	Yes (23.5 score)
Ohrstrom *et al*., 2001[57]	11	41	VBG	SF – 36	Physical function score	46 ± 24	78 ± 23	88±17	Yes (32); Yes (42 score)
Sarwer *et al*., 2010[32]	200 (198, 147)	N/A	RYGB	SF - 36	Physical function score	34.2 ± 25.5	67.5 ± 23.9	74.0 ± 21.8	Yes (33.3); Yes (39.8 score)
Tompkins *et al*., 2013[27]	25	45.5	RYGB	SF – 36	Physical function score	34.43 ± 9.63	52.14 ± 8.64	N/A	Yes (11.5 score)
Vincent *et al*., 2012[28]	25	47.0	RYGB, GB	SF – 36	Physical function score	32.1 ± 11.9	43.6 ± 11.2	N/A	Yes (17.17 score)
Wiklund *et al*., 2015[48]	70	44.7	RYGB	Disability rating index	Total score	30.4	N/A	14.2 (18 months)	Yes (16.2 DRI score)
Objective Physical Function									
Ben-Dov *et al*., 2000[55]	19	43.3	VBG	Incremental maximal cycle test	watts	124.0 ± 30.5	N/A	127.0 ± 39.2	Yes (3.0 watts)
Bond *et al*., 2008[16]	119	49.9	RYGB	Walking	min/week	170.2 ± 325	N/A	385.9 ± 458	Yes (215.7 min/week)
Da Silva *et al*., 2013[38]	17	46.0	RYGB	6 MWT	m	489.0 ± 14.0	536.0 ± 14.0	N/A	Yes (47 metres)
Da Silva *et al*., 2013[38]	17	46.0	RYGB	30% handgrip force	kgf	10 ± 0.7	9 ± 0.7	N/A	No (1kgf)
De Souza *et al*., 2010[39]	61	49.4	RYGB	Treadmill exercise test	m	401.8 ± 139.0	513.4 ± 159.9	690.5 ± 76.2	Yes (111.6); Yes (288.7 metres)
De Souza *et al*., 2009[9]	49	51.1	RYGB	6 MWT	m	381.9 ± 49.3	N/A	467.0 ± 40.3	Yes (85.1 metres)
Handrigan *et al*., 2010[8]	10	49.1	DS	Lower limb maximal force	kg	74.4 ± 15.1	58.9 ± 11.8	50.4 ± 8.6	No (15.5kg); No (24.0kg)
Hortobagyi *et al*., 2010[34]	10	43.2	RYGB	Walking speed	step/min	121.0 ± 7.5	117.0 ± 8.2	119.0 ± 8.6	Yes (4.0); Yes (2.0 step/min)
Hue *et al*., 2008[10]	10	50.2	DS	Lower limb maximal force	N	742.8 ± 131.3	N/A	493.9 ± 84.3	No (248.9 N)
Iossi *et al*., 2013[21]	39	49.0	RYGB	Timed get up and go	sec	12.6 ± 3.1	10.3 ± 2.4	9.6 ± 2.7	Yes (2.3); Yes (3.0 s)

Josbeno *et al*., 2010[22]	17	46.9	RYGB	6 MWT	m	393 ± 62.1	446 ± 41.4	N/A	Yes (53 metres)
Josbeno *et al*., 2010[22]	18	46.9	RYGB	Short physical performance battery	SPPB score	11.2 ± 1.2	11.7 ± 0.6	N/A	Yes (0.5 SPPB score)
Kanopakis *et al*., 2001[56]	16	49.0	VBG	Treadmill exercise test	s	675.0 ± 226.0	1007.0 ± 389.0	N/A	Yes (332 s)
Lyytinen *et al*., 2013[45]	16	44.0	RYGB	6 MWT	m	500.7 ± 56.8	561.4 ± 50.6	N/A	Yes (60.7 metres)
Lyytinen *et al*., 2013[45]	16	44.0	RYGB	Timed up and go	s	7.4 ± 1.7	6.35 ± 0.9	N/A	Yes (1.05 s)
Maniscalo *et al*., 2006[51]	15	42.1	GB	6 MWT	m	475.7	N/A	626.3	Yes (150.6 metres)
Maniscalo *et al*., 2007[50]	12	43.2	GB	6 MWT	m	416.5 ± 67.1	N/A	615.2 ± 104.0	Yes (198.7 metres)
Miller *et al*., 2009[24]	18	53.0	RYGB	4 meter walk time	s	5.4 ± 3.3	4.2 ±2.4	3.9 ± 1.4	Yes (1.2); Yes (2.5 s)
Miller *et al*., 2009[24]	18	53.0	RYGB	Short physical performance battery score	SPPB score	9.1 ± 1.7	10.3 ± 2.1	11.1 ± 1.3	Yes (1.2); Yes (2.0 SPPB score)
Miller *et al*., 2009[24]	16	53.0	RYGB	Maximal torque	Nm	126.3 ± 7.2	111.7 ± 36.8	97.7 ± 31.6	No (14.6); No (28.6 Nm)
Ohrstrom *et al*., 2001[57]	11	41	VBG	Walking energy expenditure	$KJ.min^{-1}$	27.4 ± 4.9	19.3±3.3	19.1 ± 3.0	Yes (8.1); Yes (8.3 $KJ.min^{-1}$)
Seres *et al*., 2006[26]	31	51.0	Not stated	Treadmill exercise test	min	13.8 ± 3.9	N/A	21.6 ± 4.3	Yes (7.8 minutes)
Tompkins *et al*., 2008[27]	25	45.5	RYGB	6 MWT	m	414.1 ± 104.0	551.5 ± 101.2	N/A	Yes (137.4 metres)
Valezi *et al*., 2011[31]	31	35.9	RYGB	Treadmill exercise test	m	378.9 ± 126.5	N/A	595 ± 140.4	Yes (216.1 metres)
Vargas *et al*., 2013[40]	67	50.5	RYGB	6 MWT	m	405.3 ± 92.3	500.1 ± 111.6	N/A	Yes (94.8 metres)
Vargas *et al*., 2013[40]	67	50.5	RYGB	Timed up and go	sec	10.0 ± 2.5	7.5 ± 1.4	N/A	Yes (2.5 s)
Vincent *et al*., 2012[28]	25	47.0	RYGB, GB	Fastest possible walking speed	cm/ s	155.0 ± 26.0	162.0 ± 27.0	N/A	Yes (7 cm/ s)
Wasmund *et al*., 2011[29]	153	47.0	RYGB	Treadmill exercise test	s	917.0 ± 358.0	N/A	1362 ± 322 (2 years)	Yes (445 s)
Wiklund *et al*., 2014[47]	37	42	RYGB	Peak grip force (Right & Left)	N	298 ± 102 (R) 295 ± 92 (L)	N/A	287 ± 62 (R) 276 ± 60 (L)	No (11 N) No (19 N)
Wiklund *et al*., 2014[47]	37	42	RYGB	6 MWD	m	532 ± 81.0	N/A	599 ± 70.5	Yes (67 metres)
Wilms *et al*., 2012[58]	18	46.3	RYGB, Sleeve	Cycle exercise test	s	518.0 ± 127.3	N/A	549 ± 165.5 (27.7 months)	Yes (31 s)
Zavala *et al*., 1984[30]	13	Not stated	RYGB	Treadmill exercise test	METs	4.6	3.8	N/A	Yes (0.8 METs)

KEY: *RYGB: Roux-en Y gastric bypass; GB: gastric banding; VBG: vertical banded gastrectomy; DS: duodenal switch; PF: physical function; 6MWT: 6 minute walk test; MET: metabolic equivalent; KJ: Kilojoule; Nm: Newton metre; SPPB: short physical performance battery; kgf: kilogram force; m: metre; min: minute; s: second; cm: centimetre; N/A: Not applicable.

References

1 Colquitt JL, Picot J, Loveman E, Clegg AJ. Surgery for obesity. *Cochrane Database of Systematic Reviews*. 2009: 1-137.

2 Egberts K, Brown WA, Brennan L, O'Brien PE. Does exercise improve weight loss after bariatric surgery? A systematic review. *Obesity surgery*. 2012; 22: 335-41.

3 Livhits M, Mercado C, Yermilov I, *et al.* Exercise following bariatric surgery: systematic review. *Obesity surgery*. 2010; 20: 657-65.

4 Jacobi D, Ciangura C, Couet C, Oppert JM. Physical activity and weight loss following bariatric surgery. *Obesity Reviews*. 2011; 12: 366-77.

5 King WC, Hsu JY, Belle SH, *et al.* Pre- to postoperative changes in physical activity: report from the Longitudinal Assessment of Bariatric Surgery-2 (LABS-2). *Surgery for Obesity and Related Diseases*. 2012; 8: 522-32.

6 Stegen S, Derave W, Calders P, Van Laethem C, Pattyn P. Physical fitness in morbidly obese patients: effect of gastric bypass surgery and exercise training. *Obesity Surgery*. 2011; 21: 61-70.

7 King WC, Chen JY, Bond DS, *et al.* Objective assessment of changes in physical activity and sedentary behavior: Pre- through 3 years post-bariatric surgery. *Obesity.* 2015; 23: 1143-50.

8 Handrigan G, Hue O, Simoneau M, *et al.* Weight loss and muscular strength affect static balance control. *International Journal of Obesity*. 2010; 34: 936-42.

9 de Souza SAF, Faintuch J, Fabris SM, *et al.* Six-minute walk test: functional capacity of severely obese before and after bariatric surgery. *Surgery for Obesity and Related Diseases.* 2009; 5: 540-43.

10 Hue O, Berrigan F, Simoneau M, *et al.* Muscle force and force control after weight loss in obese and morbidly obese men. *Obesity Surgery*. 2008; 18: 1112-8.

11 Steele T, Cuthbertson DJ, Wilding JP. Impact of bariatric surgery on physical functioning in obese adults. *Obesity Reviews*. 2015; 16: 248-58.

12 Horsley T, Dingwall O, Sampson M. Checking reference lists to find additional studies for systematic reviews. *The Cochrane Database of Systematic Reviews*. 2011: MR000026.

13 Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *British Medical Journal*. 2003; 327: 557-60.

14 Boan J, Kolotkin RL, Westman EC, McMahon RL, Grant JP. Binge eating, quality of life and physical activity improve after Roux-en-Y gastric bypass for morbid obesity. *Obesity Surgery*. 2004; 14: 341-48.

15 Bond DS, Jakicic JM, Unick JL, *et al.* Pre- to postoperative physical activity changes in bariatric surgery patients: self report vs. objective measures. *Obesity* 2010; 18: 2395-97.

16 Bond DS, Phelan S, Wolfe LG, *et al.* Becoming physically active after bariatric surgery is associated with improved weight loss and health-related quality of life. *Obesity* 2008; 17: 78-83.

17 Das SK, Roberts SB, McCrory MA, *et al.* Long-term changes in energy expenditure and body composition after massive weight loss induced by gastric bypass surgery. *American Journal of Clinical Nutrition*. 2003; 78: 22-30.

18 Frezza EE, Shebani KO, Wachtel MS. Laparoscopic gastric bypass for morbid obesity decreases bodily pain, improves physical functioning, and mental and general health in women. *Journal of Laparoendoscopic & Advanced Surgical Techniques*. 2007; 17: 440-47.

19 Gorin AA, Raftopoulos I. Effect of mood and eating disorders on the short-term outcome of laparoscopic Roux-en-Y gastric bypass. *Obesity Surgery*. 2009; 19: 1685-90.

20 Hooper MM, Stellato TA, Hallowell PT, Seitz BA, Moskowitz RW. Musculoskeletal findings in obese subjects before and after weight loss following bariatric surgery. *International Journal of Obesity* 2007; 31: 114-20.

21 Iossi MF, Konstantakos EK, Teel DD, 2nd, *et al.* Musculoskeletal function following bariatric surgery. *Obesity* 2012; 21: 1104-10.

22 Josbeno DA, Jakicic JM, Hergenroeder A, Eid GM. Physical activity and physical function changes in obese individuals after gastric bypass surgery. *Surgery For Obesity And Related Diseases*. 2010; 6: 361-66.

23 Liu X, Lagoy A, Discenza I, *et al.* Metabolic and neuroendocrine responses to Roux-en-Y gastric bypass. I: energy balance, metabolic changes, and fat loss. *The Journal of Clinical Endocrinology and Metabolism*. 2012; 97: E1440-50.

24 Miller GD, Nicklas BJ, You T, Fernandez A. Physical function improvements after laparoscopic Roux-en-Y gastric bypass surgery. *Surgery for Obesity and Related Diseases*. 2009; 5: 530-37.

25 Rosenberger PH, Henderson KE, White MA, Masheb RM, Grilo CM. Physical activity in gastric bypass patients: associations with weight loss and psychosocial functioning at 12-month follow-up. *Obesity Surgery*. 2011; 21: 1564-69.

26 Serés L, Lopez-Ayerbe J, Coll R, *et al.* Increased exercise capacity after surgically induced weight loss in morbid obesity. *Obesity* 2006; 14: 273-79.

27 Tompkins J, Bosch PR, Chenowith R, Tiede JL, Swain JM. Changes in functional walking distance and health-related quality of life after gastric bypass surgery. *Physical Therapy*. 2008; 88: 928-35.

28 Vincent HK, Ben-David K, Conrad BP, Lamb KM, Seay AN, Vincent KR. Rapid changes in gait, musculoskeletal pain, and quality of life after bariatric surgery. *Surgery For Obesity And Related Diseases*. 2012; 8: 346-54.

29 Wasmund SL, Owan T, Yanowitz FG, *et al.* Improved heart rate recovery after marked weight loss induced by gastric bypass surgery: two-year follow up in the Utah Obesity Study. *Heart Rhythm*. 2011; 8: 84-90.

30 Zavala DC, Printen KJ. Basal and exercise tests on morbidly obese patients before and after gastric bypass. *Surgery*. 1984; 95: 221-29.

31 Valezi AC, Machado VH. Morphofunctional evaluation of the heart of obese patients before and after bariatric surgery. *Obesity Surgery*. 2011; 21: 1693-7.

32 Sarwer DB, Wadden TA, Moore RH, Eisenberg MH, Raper SE, Williams NN. Changes in Quality of Life and Body Image Following Gastric Bypass Surgery. *Surgery for Obesity and Related Diseases*. 2010; 6: 608-14.

33 Hörchner R, Tuinebreijer W. Improvement of physical functioning of morbidly obese patients who have undergone a Lap-Band operation: one-year study. *Obesity Surgery*: 1999; 9: 399-402.

34 Hortobágyi T, Herring C, Pories WJ, Rider P, Devita P. Massive weight loss-induced mechanical plasticity in obese gait. *Journal Of Applied Physiology* 2011; 111: 1391-99.

35 Mathus-Vliegen EM, de Weerd S, de Wit LT. Health-related quality-of-life in patients with morbid obesity after gastric banding for surgically induced weight loss. *Surgery*. 2004; 135: 489-97.

36 Mathus-Vliegen EM, Wit LT. Health-related quality of life after gastric banding. *The British Journal of Surgery*: 2007; 94: 457-65.

37 Wouters EJ, Larsen JK, Zijlstra H, van Ramshorst B, Geenen R. Physical Activity After Surgery for Severe Obesity: the Role of Exercise Cognitions. *Obesity Surgery*. 2011; 21: 1894-99.

38 da Silva RP, Martinez D, Faria CC, *et al.* Improvement of exercise capacity and peripheral metaboreflex after bariatric surgery. *Obesity Surgery*. 2013; 23: 1835-41.

39 de Souza SAF, Faintuch J, Sant'anna AF. Effect of weight loss on aerobic capacity in patients with severe obesity before and after bariatric surgery. *Obesity Surgery*. 2010; 20: 871-75.

40 Vargas CB, Picolli F, Dani C, Padoin AV, Mottin CC. Functioning of obese individuals in pre- and postoperative periods of bariatric surgery. *Obesity Surgery*. 2013; 23: 1590-5.

41 Berglind D, Willmer M, Eriksson U, *et al.* Longitudinal Assessment of Physical Activity in Women Undergoing Roux-en-Y Gastric Bypass. *Obesity Surgery*. 2014; 25: 119-125.

42 Carrasco F, Papapietro K, Csendes A, *et al.* Changes in resting energy expenditure and body composition after weight loss following Roux-en-Y gastric bypass. *Obesity Surgery*. 2007; 17: 608-16.

43 Huang C-Y, Hsu M-C, Pan K-C, Huang C-K, Chi S-C. Early health status and health-related quality of life after laparoscopic gastric bypass surgery in morbidly obese patients. *Bariatric Nursing & Surgical Patient Care*. 2011; 6: 193-200.

44 Julia C, Ciangura C, Capuron L, *et al.* Quality of life after Roux-en-Y gastric bypass and changes in body mass index and obesity-related comorbidities. *Diabetes & Metabolism*. 2013; 39: 148-54.

45 Lyytinen T, Liikavainio T, Paakkonen M, Gylling H, Arokoski JP. Physical function and properties of quadriceps femoris muscle after bariatric surgery and subsequent weight loss. *Journal of Musculoskeletal & Neuronal Interactions*. 2013; 13: 291-300.

46 Vatier C, Henegar C, Ciangura C, *et al.* Dynamic relations between sedentary behavior, physical activity, and body composition after bariatric surgery. *Obesity Surgery*. 2012; 22: 1251-56.

47 Wiklund M, Olsén MF., Torsten O, Asa C. Physical Fitness and Physical Activity in Swedish Women before and one Year after Roux-en-Y Gastric Bypass Surgery. *The Open Obesity Journal*. 2014;6 38-43.

48 Wiklund M, Olsén MF. Physical Function and Health Related Quality of Life Before and 18 Months after Bariatric Surgery. *The Open Obesity Journal*. 2015: 12-16.

49 Colles SL, Dixon JB, O'Brien PE. Hunger control and regular physical activity facilitate weight loss after laparoscopic adjustable gastric banding. *Obesity Surgery*. 2008; 18: 833-40.

50 Maniscalco M, Arciello A, Zedda A, *et al.* Right ventricular performance in severe obesity. Effect of weight loss. *European Journal of Clinical Investigation*. 2007; 37: 270-5.

51 Maniscalco M, Zedda A, Giardiello C, *et al.* Effect of bariatric surgery on the six-minute walk test in severe uncomplicated obesity. *Obesity Surgery*. 2006; 16: 836-41.

52 Nickel C, Widermann C, Harms D, *et al.* Patients with extreme obesity: change in mental symptoms three years after gastric banding. *International Journal of Psychiatry In Medicine*. 2005; 35: 109-22.

53 Ruiz-Tovar J, Zubiaga L, Llavero C, Diez M, Arroyo A, Calpena R. Serum cholesterol by morbidly obese patients after laparoscopic sleeve gastrectomy and additional physical activity. *Obesity Surgery*. 2014; 24: 385-9.

54 Sjöström L, Lindroos AK, Peltonen M, *et al.* Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *The New England Journal of Medicine*. 2004; 351: 2683-93.

55 Ben-Dov I, Grossman E, Stein A, Shachor D, Gaides M. Marked weight reduction lowers resting and exercise blood pressure in morbidly obese subjects. *American Journal of Hypertension*. 2000; 13: 251-55.

56 Kanoupakis E, Michaloudis D, Fraidakis O, Parthenakis F, Vardas P, Melissas J. Left ventricular function and cardiopulmonary performance following surgical treatment of morbid obesity. *Obesity Surgery*. 2001; 11: 552-8.

57 Ohrström M, Hedenbro J, Ekelund M. Energy expenditure during treadmill walking before and after vertical banded gastroplasty: a one-year follow-up study in 11 obese women. *The European Journal of Surgery*. 2001; 167: 845-50.

58 Wilms B, Ernst B, Thurnheer M, Weisser B, Schultes B. Differential Changes in Exercise Performance After Massive Weight Loss Induced by Bariatric Surgery. *Obesity Surgery*. 2012; 23: 365-371.

59 Taylor HL, Jacobs DR, Jr., Schucker B, Knudsen J, Leon AS, Debacker G. A questionnaire for the assessment of leisure time physical activities. *Journal of Chronic Diseases* 1978; 31: 741-55.

60 World Health Organisation. Global Strategy on Diet, Physical Activity and Health *Physical Activity and Adults - Recommended levels of physical activity for adults aged 18 - 64 years*. WHO: 2015.

61 Tudor-Locke C, Bassett DR, Jr. How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Medicine*. 2004; 34: 1-8.

62 Wise RA, Brown CD. Minimal clinically important differences in the six-minute walk test and the incremental shuttle walking test. *Journal of Chronic Obstructive Pulmonary Disease*. 2005; 2: 125-9.

63 Alghadir A, Anwer S, Brismee JM. The reliability and minimal detectable change of Timed Up and Go test in individuals with grade 1 - 3 knee osteoarthritis. *BMC Musculoskeletal Disorders* 2015; 16: 174.

64 Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. *Journal of the American Geriatrics Society* 2006; 54: 743-9.

65 O'Brien PE, McPhail T, Chaston TB, Dixon JB. Systematic review of medium-term weight loss after bariatric operations. *Obesity Surgery*. 2006; 16: 1032-40.

66 Johannsen DL, Knuth ND, Huizenga R, Rood JC, Ravussin E, Hall KD. Metabolic Slowing with Massive Weight Loss despite Preservation of Fat-Free Mass. *The Journal of Clinical Endocrinology and Metabolism*. 2012; 97: 2489-96.

67 Shada AL, Hallowell PT, Schirmer BD, Smith PW. Aerobic exercise is associated with improved weight loss after laparoscopic adjustable gastric banding. *Obesity Surgery*. 2013; 23: 608-12.

68 Wyrwich KW, Fihn SD, Tierney WM, Kroenke K, Babu AN, Wolinsky FD. Clinically important changes in health-related quality of life for patients with chronic obstructive pulmonary disease: an expert consensus panel report. *Journal of General Internal Medicine*. 2003; 18: 196-202.

69 Josbeno DA, Kalarchian M, Sparto PJ, Otto AD, Jakicic JM. Physical activity and physical function in individuals post-bariatric surgery. *Obesity Surgery*. 2011; 21: 1243-9.

70 Castello V, Simões RP, Bassi D, Catai AM, Arena R, Borghi-Silva A. Impact of aerobic exercise training on heart rate variability and functional capacity in obese women after gastric bypass surgery. *Obesity Surgery*. 2011; 21: 1739-49.

71 Castello V, Simões PR, Beltrame T, e*t al.* Effects of aerobic exercise training on variability and heart rate kinetic during submaximal exercise after gastric bypass surgery - a randomized controlled trial. *Disability & Rehabilitation*. 2013; 35: 334-42.

72 Huck CJ. Effects of Supervised Resistance Training on Fitness And Functional Strength in Patients Succeeding Bariatric Surgery. *Journal of Strength and Conditioning Research*. 2014; 29: 589-95.