Obesity Medicine 13 (2019) 6–12

Contents lists available at ScienceDirect

Obesity Medicine

journal homepage: www.elsevier.com/locate/obmed

Changes in physical activities patterns assessed by accelerometry after bariatric surgery: A systematic review and meta-analysis

Carolina Gabriela Reis Barbosa[a], Rozangela Verlengia[a], Anna Gabriela Silva Vilela Ribeiro[a], Maria Rita Marques de Oliveira[b], Alex Harley Crisp[a,*]

[a] Programa de Pós-graduação em Ciências do Movimento Humano - Universidade Metodista de Piracicaba (UNIMEP), Piracicaba, SP, Brazil
[b] Programa de Pós-graduação em Alimentos e Nutrição - Universidade Estadual Paulista (UNESP), Araraquara, SP, Brazil

ARTICLE INFO

Keywords:
Obesity
Physical activity
Sedentary behavior
Human movement
Accelerometer

ABSTRACT

Introduction: Research into daily physical activity patterns of bariatric patients has primarily relied on self-report questionnaires. Given the importance of to moderate-to-vigorous physical activity (MVPA) as opposed to sedentary behavior for health outcomes and surgical success, more valid methods for objectively measuring physical activities are necessary.

Evidence acquisition: The main question is whether bariatric surgery, weight loss, and standard care after surgery would favor the increase of physical activity level. Therefore, we conducted a systematic review and meta-analysis of retrospective studies that investigated the changes in physical activities patterns after bariatric surgery which were evaluated by accelerometry. The search was conducted in five electronic databases (PubMed, Web of Science, Google Scholar, SPORTDiscus, and Scopus) up to December 2017. The standardized mean difference (SMD) was calculated using a random effects model with a Comprehensive Meta-Analysis program.

Evidence synthesis: A total of 10 studies met the inclusion criteria for the meta-analysis. Overall, the results indicated no significant changes to sedentary (SMD = −0.055; 95% confidence interval (CI) −0.149 to 0.040; $p = 0.161$) and light activities per day (SMD = 0.020; 95% CI −0.095 to 0.134; $p = 0.737$) post bariatric surgery. However, a positive effect was observed to MVPA per day (SMD = 0.133; 95% CI 0.040 to 0.226; $p = 0.005$) and MVPA in bouts ≥10 min per week (SMD = 0.066; 95% CI 0.039 to 0.093; $p = 0.000$).

Conclusions: In summary, bariatric surgery per se resulted only in a trivial effect on MVPA changes after body weight loss. On the other hand, bariatric surgery did not influence sedentary behavior, indicating that bariatric patients need to be better informed about the importance of reducing sedentary activities and increasing physical activity level.

1. Introduction

Bariatric surgery is recognized as an effective method to induce significant weight loss, control several comorbidities, and increase life expectancy in subjects with morbid obesity (Colquitt et al., 2014). On the other hand, over time post-surgery, many patients may regain body weight and have a recurrence of comorbidities (McGrice and Don Paul, 2015). Therefore, an interdisciplinary approach to care for bariatric patients plays a key role in the long-term success of bariatric surgery and patient health status over time.

By using an interdisciplinary approach, one of the behavioral changes that should be targeted for bariatric patients is increased physical activity, which can contribute to the effectiveness of the surgery (King and Bond, 2013; Coen and Goodpaster, 2016). Physical activity is defined as any type of body movement that results in an increase in energy expenditure above absolute rest values (Butte et al., 2012). Based on the metabolic equivalent (MET) values, defined as one kcal/kg/hour, physical activities can be classified as sedentary (< 1.5 METs), light (1.5–2.9 METs), moderate (3–5.9 METs), or vigorous (≥6 METs) (Crisp et al., 2014).

In the literature, the benefits of regularly practicing moderate-to-vigorous physical activity (MVPA) are well established in relation to the primary and secondary prevention of several chronic diseases (e.g., cardiovascular diseases, type 2 diabetes, cancer, hypertension, depression, and osteoporosis) and premature death (Warburton et al., 2006). In this context, important research associations (Haskell et al., 2007;

* Corresponding author.
E-mail address: alexhcrisp@gmail.com (A.H. Crisp).

https://doi.org/10.1016/j.obmed.2018.12.003
Received 2 May 2018; Received in revised form 19 November 2018; Accepted 5 December 2018

WHO, 2010; O'Donovan et al., 2010) recommend the practice of ≥150 min of moderate physical activity per week (accumulated in sessions ≥10 min) or ≥75 min of vigorous physical activity for adult subjects; and physical inactivity is a term used to classify individuals who do not reach the MVPA recommendations (Bouchard et al., 2015).

In addition, recent studies have indicated that a greater accumulation of sedentary activities is associated with a higher risk of morbidity and mortality, regardless of physical inactivity (Chau et al., 2014; Ekelund et al., 2016). Sedentary behavior is a component of physical inactivity, which is characterized as any activity during waking hours that requires low energy expenditure (< 1.5 METs) while in a sitting or reclining position (Sedentary Behaviour Research Network, 2012).

Regarding bariatric surgery, two systematic reviews of observational studies reported that higher physical activity level during the postoperative period appears to be associated with a greater weight loss (Jacobi et al., 2011; Livhits et al., 2010). However, it is important to note that a large part of the included studies in the systematic reviews used self-report questionnaires to determine the participant's physical activity patterns. The great subjectivity regarding the intensity of physical activity performed and possible bias in the responses of self-report questionnaires are both potential limitations of these studies, especially for the obese population.

In this sense, Bond et al. (2010a) compared MVPA changes before and six months after bariatric surgery by using a self-report physical activity survey instrument (Paffenbarger Physical Activity Questionnaire) with data obtained using the tri-axial accelerometer. The results obtained from the self-report questionnaire showed a five-fold increase for MVPA pre-to post-surgery. On the other hand, the accelerometer detected insignificant decreases in MVPA (Bond et al., 2010a).

Given the importance of MVPA, as opposed to sedentary behaviors, for health outcomes and surgical success, more valid methods for objectively measuring physical activity are necessary. Tri-axial accelerometers are portable devices that directly measure the body movement acceleration in three axes (vertical, antero-posterior, and mediolateral). These devices are able to quantify the frequency, duration, and intensity of daily physical activity (Butte et al., 2012). Therefore, we conducted a systematic review and meta-analysis of retrospective studies that investigated the changes in the physical activity patterns of patients after bariatric surgery which were evaluated by accelerometry.

2. Evidence acquisition

2.1. Search strategy

The review procedures followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement guidelines (Moher et al., 2009). The search was conducted in five electronic databases (PubMed, Web of Science, Google Scholar, SPORTDiscus, and Scopus) up to December 2017, with no language restrictions. The terms used for the search were “bariatric surgery” AND [“physical activity” OR “sedentary behavior”] AND accelerometry. After the exclusion of duplicate studies, two investigators (CGRB and AHC) independently screened the titles and abstracts to select articles relevant to the topic of this study.

2.2. Eligibility criteria

Studies were eligible based on the following inclusion criteria: (1) prospective longitudinal study; (2) published in peer-reviewed scientific journal; (3) included obese subjects (BMI ≥ 35 kg/m^2) submitted to bariatric surgery; (4) age ≥18 years; (5) used tri-axial accelerometer to objectively measure sedentary activity or light activity or MVPA. The exclusion criteria were as follows: (1) reported results only from pre- or post-surgery; (2) used self-report questionnaires to determine physical activities patterns; (3) data analyses lower than six months post-surgery; and (4) abstracts from conferences and unpublished studies. Full-text articles were assessed independently for eligibility by two reviewers (CGRB and AHC). Disagreement on the inclusion or exclusion of studies was resolved by consensus, or, if necessary, by the participation of a third reviewer (RV). In addition, the reference list of the eligible studies was also analyzed to identify potentially relevant studies.

2.3. Data extraction

The same two reviewers (CGRB and AHC) independently extracted the following data from each eligible study: the first author's name; publication year; country; number of subjects; pre-surgery age, pre-surgery body mass index (BMI); accelerometer type; surgical procedure; analysis time; and main results. In addition, the mean and standard deviation values of the following variables were extracted: sedentary activity (min/day or %/day); light activity (min/day or %/day); and MVPA (min/day or %/min and min/week in bouts ≥ 10 min). For the studies that presented data only in graph form, the data were extracted using the program WebPlotDigitizer –version 3.8. The studies that presented the outcome values with standard error (SE) were converted to standard deviation according to the formula: $SD = SE * \sqrt{N}$. Disagreement on the data extraction was resolved by consensus.

2.4. Statistical analysis

The meta-analysis was performed using the random effects model for each outcome variable (sedentary activity, light activity, and MVPA) using the software “Comprehensive Meta-analysis” version 3.3.070 (Biostat Inc., Englewood, NJ, USA). The standardized mean difference (SMD) with 95% confidence interval (CI) was calculated with the following data entry: pre mean; pre SD; post mean; post SD; pre-to post-correlation; and sample size. A subgroup analysis of studies was performed to verify the influence of time post-surgery (six to 11 months or ≥ 12 months) on physical activities. The pre-to post-correlation was estimated with the following formula: $r = (S^2_{pre} + S^2_{post} - S^2_D)/2 \times (S_{pre} \times S_{post})$; where S is the standard deviation, and S_D is the standard deviation of difference score (pre-to post-surgery). S_D was estimate with the following formula: S_D = root square $[(S^2_{pre}/n) + (S^2_{post}/n)]$. The level of significance was $p \leq 0.05$. The magnitude of Cohen's d SMD was interpreted according to the following threshold: ≤0.19 as trivial effect, 0.20–0.49 as small effect; 0.50–0.79 as moderate effect; and ≥0.80 as large effect.

2.5. Heterogeneity and sensitivity analysis

The heterogeneity between studies was assessed by I^2 inconsistency test. Values of > 50% were considered evidence of substantial heterogeneity. A sensitivity analysis excluding one study at a time was performed, and then the outcome was examined to ensure that the results were not simply due to one large study or a study with an extreme result. Studies were considered influential if removal resulted in a change of SMD from significant ($p < 0.05$) to non-significant ($p > 0.05$).

3. Evidence synthesis

3.1. Study selection

The search strategy identified 2423 records in the electronic databases (PubMed, Web of Science, Google Scholar, SPORTDiscus, and Scopus). After a review of titles and abstracts, 35 studies were selected for full-text review and according to the inclusion/exclusion criteria, 11 studies were considered eligible. The main reasons for exclusion were: data from only pre-surgery (n = 8); data from only post-surgery (n = 7); used bi-axial accelerometer (n = 2); and not relevant variables to study purpose (n = 7). In the meta-analyses, 10 studies were

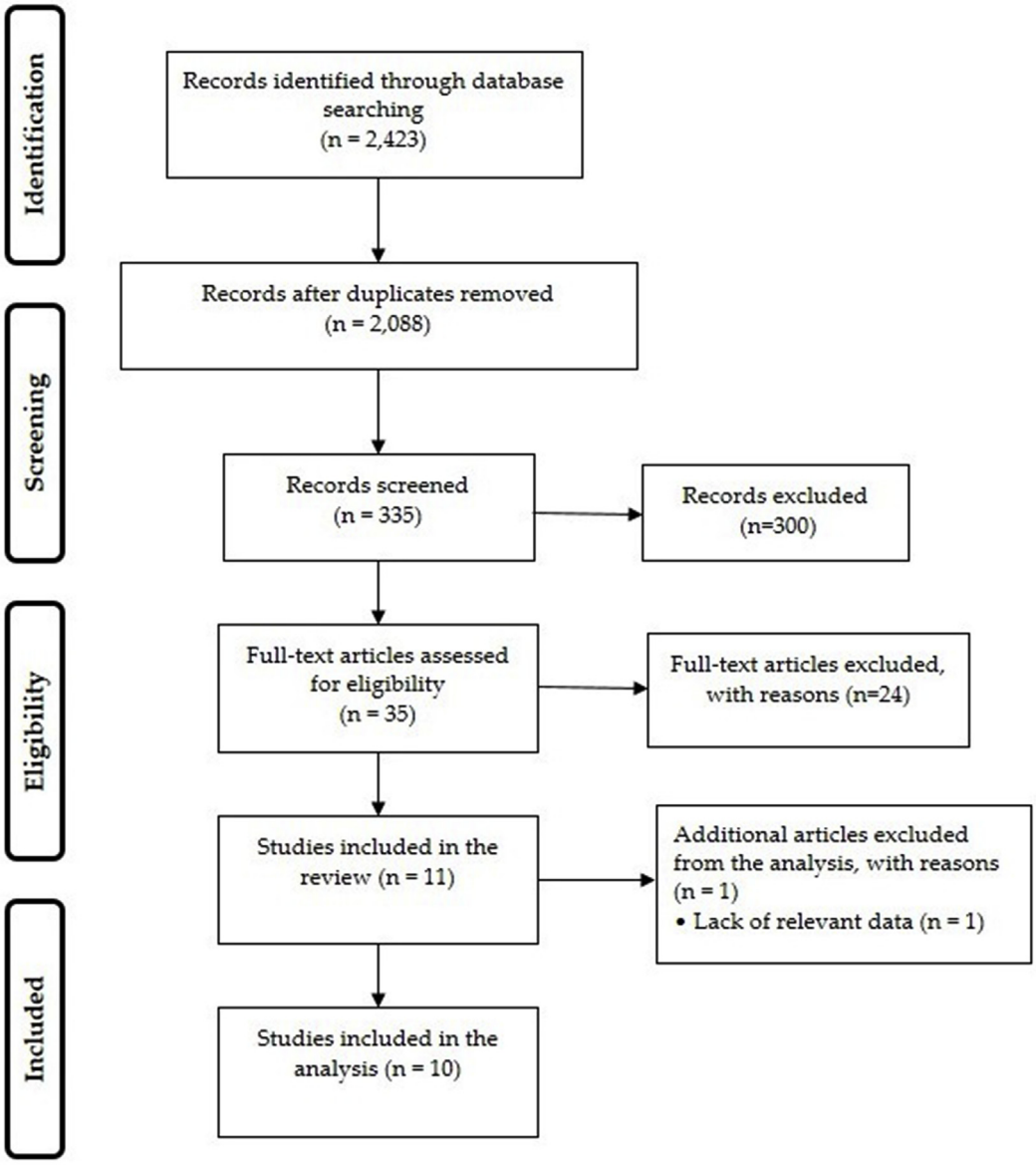

Fig. 1. Flowchart of the search and study selection process.

included. The study by Babineau et al. (2015) was not included in the meta-analysis owing to not reporting the pertinent data (sedentary activity, light activity, and MVPA). In the studies by Creel et al. (2016) and Bond et al. (2017) was included in the meta-analysis only the data from the control group (standard care), who did not receive counseling to increase physical activity pattern before and after surgery. Fig. 1 illustrates the flowchart of the article selection process for the systematic review and meta-analysis.

3.2. Study characteristics

The general characteristics and results of each eligible study are summarized in Table 1. The studies (n = 11) were published from 2010 to 2017 and included a total of 375 subjects. These studies were conducted in Brazil (Crisp et al., 2017), Canada (Babineau et al., 2015), USA (Bond et al., 2010a, 2017; Creel et al., 2016; Wefers et al., 2017), Sweden (Berglind et al., 2015a,b; Berglind et al., 2015b; Berglind et al., 2016; Sellberg et al., 2017) and England (Afshar et al., 2017). Most studies were conducted on female subjects with ages ranging from 31 to 48 years. Seven studies (Babineau et al., 2015; Crisp et al., 2017; Wefers et al., 2017; Berglind et al., 2015a,b; Berglind et al., 2016; Sellberg et al., 2017) evaluated the physical activities' changes after RYGB surgery and four studies (Bond et al., 2010a, 2017; Creel et al., 2016; Afshar et al., 2017) combined different surgical procedures. The follow-up interval from the pre-to post-surgery period ranged from two months to five years.

3.3. Meta-analysis

Eight studies that evaluated the changes in sedentary and light activity pre-to post-surgery were included in the meta-analysis, resulting in 10 outcome measures in 390 subjects. In the study by Crisp et al. (2018) data were included at six and 12 months after surgery. The study by Sellberg et al. (2017) presented data from nine and 48 months after surgery. Overall, the meta-analysis using the random effects model indicated no significant changes to sedentary (SMD = −0.055; 95% CI −0.149 to 0.040; $p = 0.260$; $I^2 = 96.9\%$) and light activities per day (SMD = 0.020; 95% CI −0.095 to 0.134; $p = 0.737$; $I^2 = 96.9\%$) post bariatric surgery. Subgroup analysis also showed no significant effect on sedentary and light activities at six to 11 months post-surgery and ≥12 months post-surgery. Sensitivity analyses showed that results from sedentary activity and light activity were not affected by any particular

Table 1
Summary of the included studies.

Studies	Subjects (gender)	Age (BMI)	Accelerometer (wear)	Surgical Procedure	Analysis Time	Main Results (pre- to post-surgery)
Afshar et al. (2017)	22 (72% female)	46 years (41 kg/m^2)	Tri-axial GENEActiv (wrist)	77% GB; 18% SG; 5% IB	Before and 6 months after surgery	Sedentary (min/day): NS Light activity (min/day): NS MVPA (min/day): NS MVPA in bouts ≥10 min (min/week): NS
Babineau et al. (2015)	17 (58.5% Female)	46 years (48 kg/m^2)	Tri-axial ActivPAL (mid-thigh)	RYGB	Before, 3 and 6 months after surgery	Sitting/lying time: NS
Berglind et al. (2016)	43 (100% female)	39 years (39 kg/m^2)	Tri-axial GT3X+ (hip)	RYGB	Before and 9 months surgery	Sedentary (min/day): NS Light activity (min/day): NS MVPA (min/day): NS MVPA in bouts ≥10 min (min/week): NS
Berglind et al. (2015a)	56 (100% female)	39 years (37 kg/m^2)	Tri-axial GT3X+ (hip)	RYGB	Before and 9 months after surgery	Sedentary (min/day): NS Light activity (min/day): NS MVPA (min/day): NS MVPA in bouts ≥10 min (min/week): NS
Berglind et al., (2015b)	56 (100% female)	39 years (39 kg/m^2)	Tri-axial GT3X+ (hip)	RYGB	Before and 9 months after surgery	Sedentary (min/day): NS Light activity (min/day): NS MVPA (min/day): NS MVPA in bouts ≥10 min (min/week): NS
Bond et al., (2017)	14 (78.6% female)	48 years (46 kg/m^2)	Tri-axial SenseWear Armband (arm)	50% RYGB; 44% GB; 6% SG.	Before and 6 months after surgery	MVPA (min/day): ↑
Bond et al. (2010a)	20 (85% female)	47 years (50 kg/m^2)	Tri-axial RT3 (waist)	65% LAGB; 35% GB	Before and 6 months after surgery	MVPA in bouts ≥10 min (min/week): NS
Creel et al. (2016)	33 (84% female)	44 years (47 kg/m^2)	Tri-axial GT3X (hip)	RYGB SG GB r-RYGB DS	Before, 2, 4, and 6 months after surgery	6 months: Sedentary (min/day); NS 6 months: Light activity (min/day); NS 6 months: MVPA (min/day); ↑ 6 months: MVPA in bouts ≥10 min (min/week); ↑
Crisp et al. (2018)	34 (100% female)	31 years (44 kg/m^2)	Tri-axial GT3X+ (waist)	RYGB	Before, 6 and 1 year after surgery	6 months: Sedentary (%); NS 6 months: Light activity (%); NS 6 months: MVPA (%); ↑ 6 months: MVPA in bouts ≥10 min (min/week); NS 1 year: Sedentary (%); NS 1 year: Light activity (%); NS 1 year: MVPA (%); NS 1 year: MVPA in bouts ≥10 min (min/week): NS
Sellberg et al. (2017)	30	38 years (39 kg/m^2)	Tri-axial GT3X+ (hip)	RYGB	Before, 9 and 48 months after surgery	9 months: Sedentary (min/day); NS 4 years: Sedentary (min/day); NS 9 months: Light activity (min/day); NS 4 years: Light activity (min/day); NS 9 months: MVPA (min/day); NS 4 years: MVPA (min/day); NS
Wefers et al. (2017)	50 (86% female)	42 years (38 kg/m^2)	Tri-axial SenseWear Pro Arnband (arm)	RYGB	Before and 9 months after surgery	Sedentary (min/day): ↓ Light activity (min/day): ↑ MVPA (min/day): ↑

Legend: GB = gastric by-pass; SG = sleeve gastrectomy; B = intragastric balloon; RYGB = roux-en-Y gastric by-pass; rRYGB = revision Roux-en-Y gastric bypass; DS = duodenal switch; MVPA = moderate to vigorous physical activity; LAGB = laparoscopic adjustable gastric band; BD = biliopancreatic diversion with duodenal switch; BMI = body mass index; NS = non-significant changes compared to pre-surgery values; ↑ = increase compared to pre-surgery values; ↓ decrease compared to pre-surgery values.

study. Fig. 2A and B shows the forest plot of changes in sedentary and light activity, respectively.

Eight studies evaluating the changes of MVPA per day pre-to post-surgery were included in the meta-analysis, resulting in 11 outcome measures in 404 subjects. Crisp et al. (2018) presented the data from six and 12 months after surgery and Sellberg et al. (2017) from nine and 48 months after surgery. Overall, bariatric surgery favors an increase in MVPA, with SMD values of 0.133 (95% CI 0.040 to 0.226; $p = 0.005$; $I^2 = 97.0\%$). Six studies evaluating the changes of MVPA in bouts ≥10 min per week pre-to post-surgery were included in the meta-analysis, resulting in eight outcome measures in 300 subjects. Crisp et al. (2018) presented data from six and 12 months post-surgery. Overall, MVPA in bouts ≥10 min per week also increased after surgery, with SMD values of 0.066 (95% CI 0.039 to 0.093; $p = 0.000$; $I^2 = 95.6\%$). Subgroup analysis showed increase of MVPA per day at six to 11 months post-surgery (SMD = 0.297, 95% CI 0.076 to 0.519; $p = 0.008$; $I^2 = 94.1\%$) and increase of MVPA in bouts ≥10 min per week at ≥12 months post-surgery (SMD = 0.064, 95% CI 0.037 to

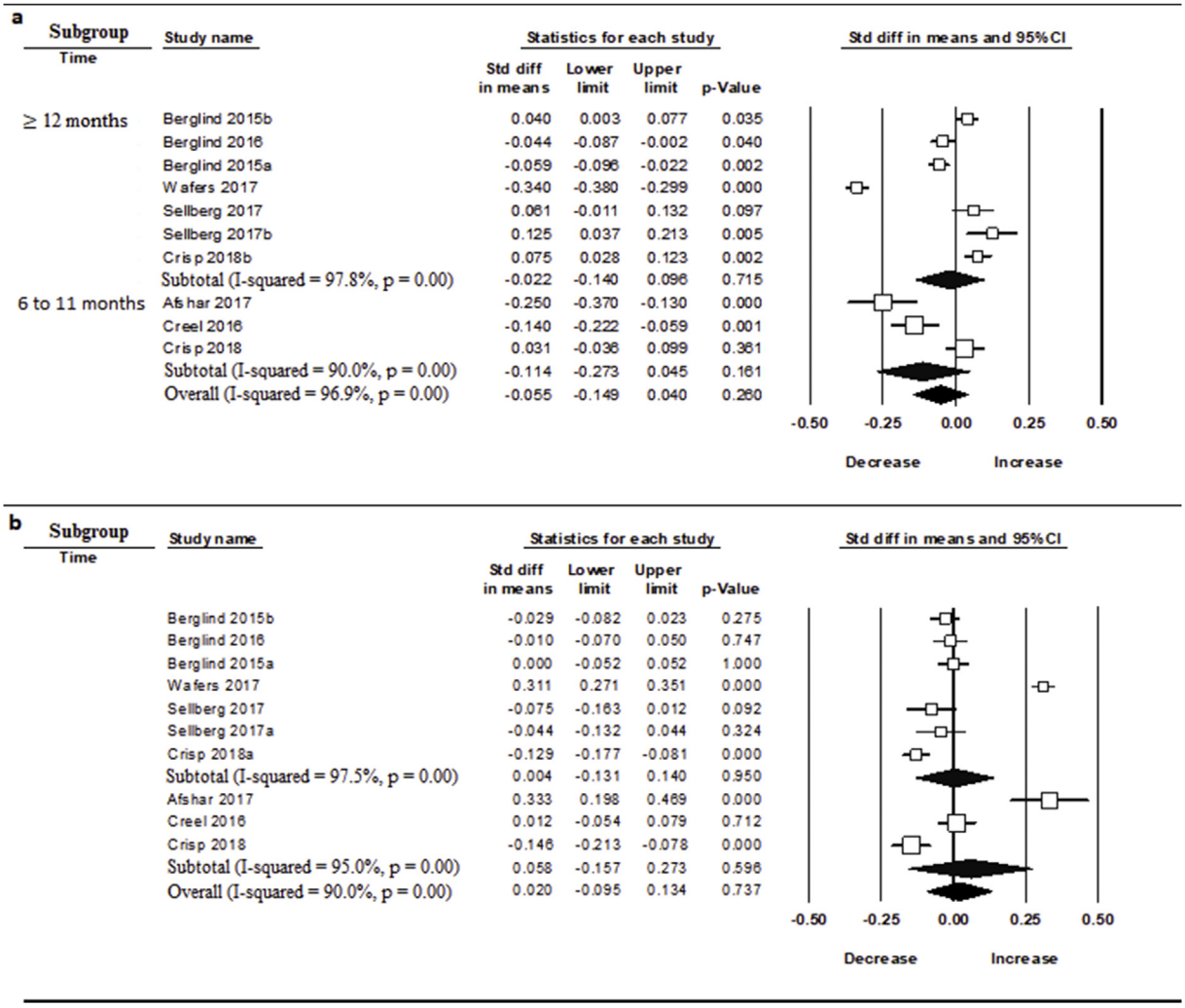

Fig. 2. Forest plot of standardized mean difference with 95% confidence interval (CI) pre-to post-surgery changes in (a) sedentary activity and (b) light activity. The size of the plotted squares reflects the relative weight of each study. The horizontal lines denote 95% CI. The rhombi represent the combined effect sizes for subgroups and overall analysis.

0.091; $p = 0.000$; $I^2 = 24.4\%$). Sensitivity analyses showed that the results from MVPA were not affected by any particular study. Fig. 3A and B shows the forest plot of the changes in MVPA per day and in bouts ≥10 min per week, respectively.

4. Discussion

To the best of our knowledge, this is the first meta-analysis of retrospective studies investigating the change in physical activity patterns by tri-axial accelerometry post-bariatric surgery. Our main findings indicate that bariatric surgery has a positive trivial effect on MVPA (per day and in sessions ≥ 10 min per week), with no changes in sedentary and light activities. Subgroup analysis based on time post-surgery also showed no significant changes in sedentary and light activities per day. However, bariatric surgery has a small effect on MVPA per day at 6–11 months post-surgery and a trivial effect on MVPA in sessions ≥10 min per week at ≥ 12 months post-surgery.

Morbidly obese subjects may have several physical barriers, including health-related issues such as physical limitations, tiredness, and bodily pain (McIntosh et al., 2016; Zabatiero et al., 2016, 2018). Consequently, they performed less MVPA throughout the day compared to normal-weight control subjects (Bond et al., 2010b). On the other hand, observational studies indicate that weight loss after bariatric surgery is associated with improvement in fibromyalgia symptoms (Saber et al., 2008), arthritis (Ahroni et al., 2005), and joint pain in the knee (Peltonen et al., 2003; Korenkov et al., 2007), hip, and ankle (Peltonen et al., 2003); all of which are factors that may favor an increase in physical activity.

However, the overall meta-analysis showed that bariatric surgery has only a trivial increase in MVPA (per day and in session ≥ 10 min per week), without affecting the time spent in sedentary and light activities. Therefore, the results from this review reinforce that weight loss post-surgery does not significantly favor changes in daily physical activities per se, and the amount of changes in MVPA cannot be considered sufficient to confer important health benefits to bariatric patients.

In bariatric surgery candidates, many physical activity barriers (such as lack of motivation and time, environment, social support, and restricted resources) are non-obesity-related (Zabatiero et al., 2016, 2018). This may explain why bariatric surgery and weight loss have only a trivial effect on MVPA and no effect on sedentary behavior. Thus, more specific behavior interventions focusing on non-obesity-related barriers should be considered to increase MVPA more effectively and to reduce sedentary behavior. In support of this, Bond et al. (2017) conducted a randomized controlled trial in bariatric surgery candidates showing that face-to-face physical activity counseling was more effective in promoting MVPA and the number of steps than standard care controls, and these changes were maintained 6 months after bariatric

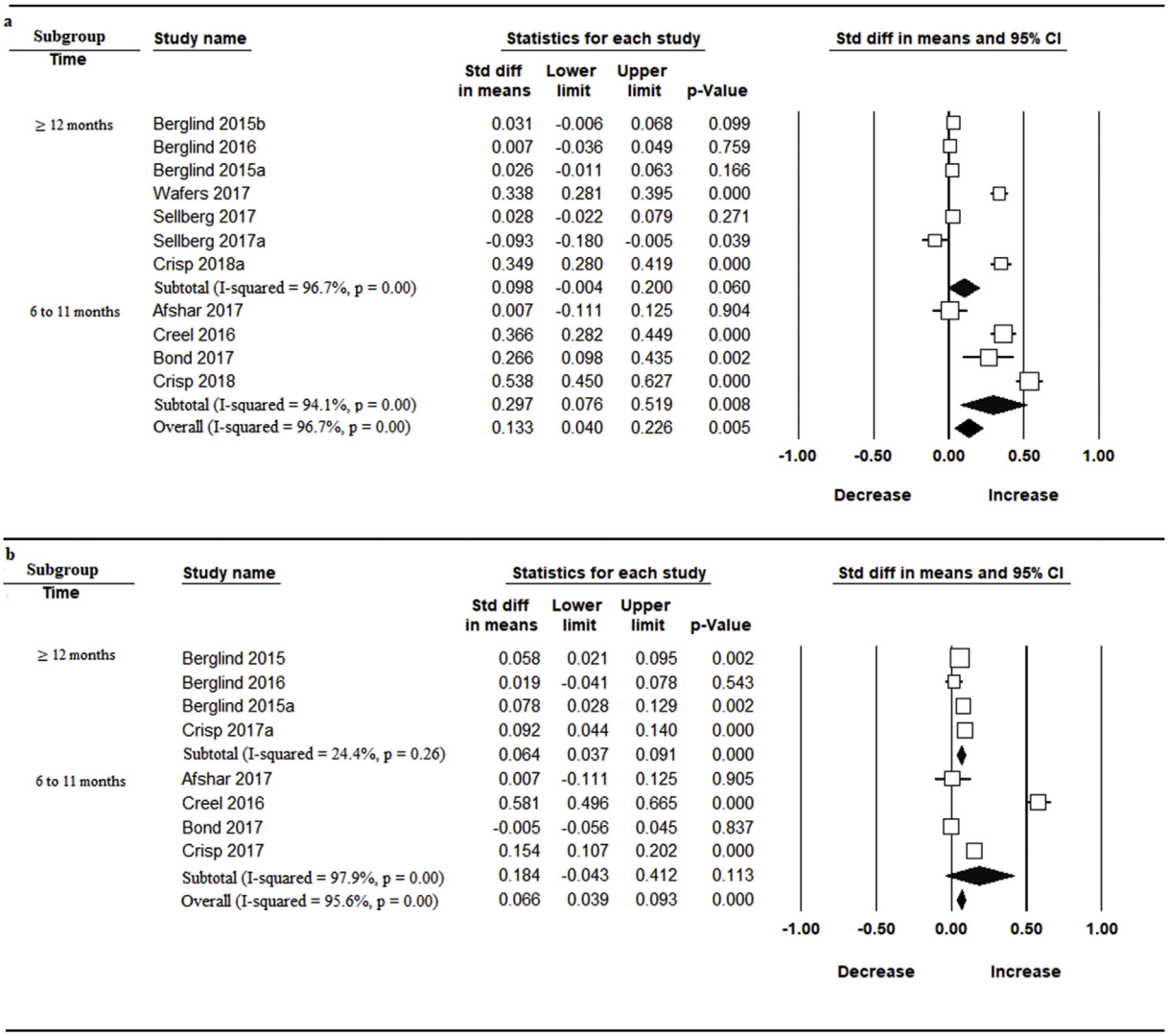

Fig. 3. Forest plot of standardized mean difference with 95% CI pre-to post-surgery changes in (a) MVPA per day and (b) MVPA in bouts ≥10 min. The size of the plotted squares reflects the relative weight of each study. The horizontal lines denote 95% confidence interval (CI). The rhombi represent the combined effect sizes for subgroups and overall analysis.

surgery.

The strength of this systematic review is that all studies assessed physical activity parameters (sedentary activities, light activities, and MVPA) by using a tri-axial accelerometer. On the other hand, there were several limitations that must be addressed. First, there was significant heterogeneity among included studies. This was not surprising, given that daily physical activity is the most variable component of total energy expenditure among individuals, and the included studies were conducted in different countries. Other sources of heterogeneities included the differences in patient characteristics (e.g., gender, age, and initial BMI), surgical procedure type (predominantly restrictive, malabsorptive, and mixed restrictive/malabsorptive), and time of analysis post-surgery. Second, we excluded data less than 6 months post-surgery. Only two studies evaluated this period (Babineau et al., 2015; Creel et al., 2016), moment when diet is more restrictive and there is accentuated loss in body weight. In addition, only one study evaluated the physical activities by tri-axial accelerometer in a period of time greater than 12 months. Thus, more studies are needed to investigate the changes in physical patterns in the long term after bariatric surgery.

In summary, bariatric surgery and standard care per se resulted in a trivial effect on MVPA after loss in body weight. On the other hand, bariatric surgery did not influence sedentary behavior, indicating that bariatric patients need to be better informed about the importance of reducing sedentary activities and increasing physical activity levels.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Funding

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.obmed.2018.12.003.

References

Afshar, S., Seymour, K., Kelly, S.B., Woodcock, S., van Hees, V.,T., Mathers, J.C., 2017. Changes in physical activity after bariatric surgery: using objective and self-reported measures. Surg. Obes. Relat. Dis. 13, 474–483.

Ahroni, J.H., Montogomery, K.F., Watkins, B.M., 2005. Laparoscopic adjustable gastric banding: weight loss, co-morbidities, medication usage and quality of life at one year. Obes. Surg. 15, 641–647.
Babineau, O., Carver, T.E., Reid, R.E.R., Christou, N.V., Andersen, R.E., 2015. Objectively monitored physical activity and sitting time in bariatric patients pre- and post-surgery. J. Obes. Bariatrics 2, 1–5.
Berglind, D., Willmer, M., Tynelius, P., Ghaderi, A., Näslund, E., Rasmussen, F., 2016. Accelerometer-measured versus self-reported physical activity levels and sedentary behavior in women before and 9 months after Roux-en-Y gastric bypass. Obes. Surg. 26, 1463–1470.
Berglind, D., Willmer, M., Eriksson, U., Thorell, A., Sundbom, M., Uddén, J., Raoof, M., Hedberg, J., Tynelius, P., Näslund, E., Rasmusses, F., 2015a. Longitudinal assessment of physical activity in women undergoing Roux-en-Y gastric bypass. Obes. Surg. 25, 119–125.
Berglind, D., Willmer, M., Tynelius, P., Ghaderi, A., Näslund, E., Rasmussen, F., 2015b. Women undergoing Roux-en-Y Gastric Bypass surgery: family resemblance in pre- to postsurgery physical activity and sedentary behavior in children and spouses. Surg. Obes. Relat. Dis. 11, 690–699.
Bond, D.S., Jakicic, J.M., Unick, J.L., Vithiananthan, S., Pohl, D., Roye, G.D., Ryder, B.A., Sax, H.C., Wing, R.R., 2010a. Pre- to postoperative physical activity changes in bariatric surgery patients: self report vs. objective measures. Obesity 18, 2395–2397.
Bond, D.S., Jakicic, J.M., Vithiananthan, S., Thomas, J.G., Leahey, T.M., Sax, H.C., Pohl, D., Roye, G.D., Ryder, B.A., Wing, R.R., 2010b. Objective quantification of physical activity in bariatric surgery candidates and normal-weight controls. Surg. Obes. Relat. Dis. 6, 72–78.
Bond, D.S., Thomas, J.G., Vithiananthan, S., Unick, J., Webster, J., Roye, G.D., Ryder, B.A., Sax, H.C., 2017. Intervention-related increases in preoperative physical activity are maintained 6-months after Bariatric surgery: results from bari-active trial. Int. J. Obes. 41, 467–470.
Bouchard, C., Blair, S.N., Katzmarzyk, P.T., 2015. Less sitting, more physical activity, or higher fitness? Mayo Clin. Proc. 90, 1533–1540.
Butte, N.F., Ekelund, U., Westerterp, K.R., 2012. Assessing physical activity using wearable monitors: measures of physical activity. Med. Sci. Sports Exerc. 44, S5–S12.
Chau, J.Y., Grinseit, A., Midthjell, K., Holmen, J., Holmen, T.L., Bauman, A.E., van der Ploeg, H.P., 2014. Cross-sectional associations of total sitting and leisure screen time with cardiometabolic risk in adults. Results from the HUNT Study, Norway. J. Sci. Med. Sport 17, 78–84.
Coen, P.M., Goodpaster, B.H., 2016. A role for exercise after bariatric surgery? Diabetes Obes. Metab. 18, 16–23.
Colquitt, J.L., Pickett, K., Loveman, E., Frampton, G.K., 2014. Surgery for weight loss in adults. Cochrane Database Syst. Rev. 8, CD003641.
Creel, D.B., Schuh, L.M., Reed, C.A., Gomez, A.R., Hurst, L.A., Stote, J., Cacucci, B.M., 2016. A randomized trial comparing two interventions to increase physical activity among patients undergoing bariatric surgery. Obesity 24, 1660–1668.
Crisp, A.H., Verlengia, R., Oliveira, M.R.M., 2014. Limitações da utilização do equivalente metabólico (MET) para a estimativa do gasto energético em atividades físicas. Rev. Bras. Cienc. Mov. 22, 148–153.
Crisp, A.H., Verlengia, R., Ravelli, M.N., Junior, I.R., de Olivera, M.R.M., 2018. Changes in physical activities and body composition after roux-Y gastric bypass surgery. Obes. Surg. 28, 1665–1671.
Ekelund, U., Steene-Johannessen, J., Brown, W.J., Fagerland, M.W., Owen, N., Powell, K.E., Bauman, A., Lee, I.M., 2016. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. Lancet 388, 1302–1310.
Haskell, W.L., Lee, I.M., Pate, R.R., Powell, K.E., Blair, S.N., Franklin, B.A., Macera, C.A., Heath, G.W., Thompson, P.D., Bauman, A., 2007. Physical activity and public health: updated recommendation for adults from American college of sports medicine and the American heart association. Med. Sci. Sports Exerc. 39, 1423–1434.
Jacobi, D., Ciangura, C., Couet, C., Oppert, J.M., 2011. Physical activity and weight loss following bariatric surgery. Obes. Rev. 12, 366–377.
King, W.C., Bond, D.S., 2013. The importance of preoperative and postoperative physical activity counselling in bariatric surgery. Exerc. Sport Rev. 41, 26–35.
Korenkov, M., Shah, S., Sauerland, S., Duenschede, F., Junginger, T., 2007. Impact of laparoscopic adjustable gastric banding on obesity co-morbidities in the medium- and long-term. Obes. Surg. 17, 679–683.
Livhits, M., Mercado, C., Yermilov, I., Parikn, J.A., Dutson, E., Mehran, A., Ko, C.Y., Gibbons, M.M., 2010. Exercise following bariatric surgery: systematic review. Obes. Surg. 20, 657–665.
McGrice, M., Don Paul, K., 2015. Interventions to improve long-term weight loss in patients following bariatric surgery: challenges and solutions. Diabetes Metab. Obes. 8, 263–274.
McIntosh, T., Hunter, D.J., Royce, S., 2016. Barriers to physical activity in obese adults: a rapid evidence assessment. J. Res. Nurs. 21, 271–287.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., PRISMA, Group., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 339, b2535.
O'Donovan, G., Blazevich, A.J., Boreham, C., Cooper, A.R., Crank, H., Eklund, U., et al., 2010. The ABC of physical activity for health: a consensus statement from British association of sport and exercise sciences. J. Sports Sci. 28, 573–591.
Peltonen, M., Lindroos, A.K., Torgerson, J.S., 2003. Musculoskeletal pain in the obese: a comparison with a general population and long-term changes after conventional and surgical obesity treatment. Pain 104, 549–557.
Saber, A.A., Boros, M.J., Mancl, T., Elgamal, M.H., Song, S., Wisadrattanapong, T., 2008. The effect of laparoscopic Roux-en-Y gastric bypass on fibromyalgia. Obes. Surg. 18, 652–655.
Sedentary Behaviour Research Network, 2012. Letter to the editor: standardized use of the terms “sedentary” and “sedentary behaviours”. Appl. Physiol. Nutr. Metab. 37, 540–542.
Sellberg, F., Willmer, M., Tynelius, P., Berglind, D., 2017. Four years' follow-up changes of physical activity and sedentary time in women undergoing roux-en-Y gastric bypass surgery and appurtenant children. BMC Surg. 17, 133.
Warburton, D.E., Nicol, C.W., Bredin, S.S., 2006. Health benefits of physical activity: the evidence. CMAJ 174, 801–809.
Wefers, J.F., Woodlief, T.L., Carnero, E.A., Helbling, N.L., Anthony, S.J., Dubis, G.S., Jakicic, J.M., Houmard, J.A., Goodpaster, B.H., Coen, P.M., 2017. Relationship among physical activity, sedentary behaviors, and cardiometabolic risk factors during gastric bypass surgery-induced weight loss. Surg. Obes. Relat. Dis. 13, 210–219.
World Heath Organization (WHO), 2010. Global Recommendations on Physical Activity for Health.
Zabatiero, J., Hill, K., Gucciardi, D.F., Hamdorf, J.M., Taylor, S.F., Hagger, M.S., et al., 2016. Beliefs, barriers and facilitators to physical activity in bariatric surgery candidates. Obes. Surg. 26, 1097–1109.
Zabatiero, J., Smith, A., Hill, K., Hamdorf, J.M., Taylor, S.F., Hagger, M.S., et al., 2018. Do factors related to participation in physical activity change following restrictive bariatric surgery? A qualitative study. Obes. Res. Clin. Pract. 12, 307–316.