Patterns of Change in Device-based Physical Activity and Sedentary Time Following Bariatric Surgery: A Longitudinal Observational Study

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Abstract

Purpose: To investigate changes in physical activity (PA) and sedentary time (ST) over 12 months following bariatric surgery.

Methods: Pre-surgery and at three, six, nine and 12 months post-surgery, wearable devices were used to measure PA at different intensities, grouped according to energy expenditure and daily step count, and ST. Measures were also collected of weight and self-efficacy for exercise. Pre- and 12 months post-surgery, measures were collected of body composition and cardiovascular fitness.

Results: Thirty adults scheduled for bariatric surgery were recruited (20 females, 44.1 [range, 22.0 to 65.0] years, body mass index 39.6 [range, 30.9 to 50.9] kg/m^2). When compared to pre-surgery measures, over the 12 months post-surgery, there were no changes in the percentage of waking hours (mean [95% CI]) spent in ST (-2% [-6 to 3]), light intensity PA (1% [-3 to 5]), and moderate-to-vigorous intensity PA (1% [-1 to 3]). At all time points, participants spent most (>70%) of their waking hours accumulating ST, with little time spent in light intensity PA (~21%) and almost no time in moderate-to-vigorous intensity PA (~5%). Step count and cardiovascular fitness were also unchanged. There were significant changes in weight, self-efficacy for exercise and body composition.

Conclusions: Although bariatric surgery resulted in substantial weight loss and improved self-efficacy for exercise, it was insufficient to effect change in PA, ST or cardiovascular fitness. Complementing surgical intervention with behavioral interventions may optimize change in PA and ST.

Keywords: physical activity; sedentary time; bariatric surgery; self-efficacy

Highlights:

- Device-based physical activity and sedentary time do not change post-surgery
- The majority of waking hours were spent accumulating sedentary time
- Little time was spent in light or moderate-to-vigorous intensity physical activity

1 Introduction

Data collected using wearable devices shows that candidates for bariatric surgery participate in low levels of physical activity (PA) and spend most of their waking hours in sedentary behaviors [1-6]. These findings are corroborated by reports that this population finds participation in regular PA challenging [7], and associate it with negative experiences and low self-efficacy [8]. Perhaps surprisingly, despite the resolution of many weight-related barriers to regular participation in PA, emerging data suggest that these behaviors show little, if any, change following bariatric surgery [9-15]. This is of concern because those who participate in greater amounts of PA following bariatric surgery may experience greater weight loss [16, 17], reductions in cardiometabolic risk factors [18], positive body composition changes [19], and better quality of life [15].

The primary aim of this study was to investigate change in device-based measures of PA and sedentary time (ST) over the first 12 months following bariatric surgery. We extend earlier work in this area in three ways. First, measures were collected using devices attached to the ankle and upper arm. These are likely to provide more accurate estimates of PA than the commonly-used waist-mounted devices, as large amounts of abdominal adipose tissue may result in the waist-mounted devices being tilted away from the body, which compromises their sensitivity to detect PA [9, 12, 14, 15]. Second, we report on the magnitude and time course of any change in PA and ST, as well as any change in the way in which time in these behaviors were accumulated. These data will provide detailed information regarding possible lifestyle targets to optimize participation in PA and reduce ST. Third, we also report on changes in weight, self-efficacy for exercise, body composition and cardiovascular fitness, with the goal of exploring any associations between the magnitude of these changes and the magnitude of changes in PA or ST, should any be identified.

2 Methods

2.1 Study design and participants

This was a longitudinal observational study. Adults aged ≥ 18 years, with a body mass index (BMI) >30 kg/m^2 who were scheduled to undergo primary laparoscopic adjustable gastric banding [LAGB] or sleeve gastrectomy [SG] were eligible to participate. Exclusion criteria comprised: (i) pregnancy or planning pregnancy within 12 months, (ii) presence of a permanent health condition such as a neurological, cardiovascular or orthopedic disease that could compromise the performance of daily PA, (iii) body weight over 160 kg (due to weight limit of equipment used for assessment of body composition and cardiovascular fitness), and (iv) cognitive impairments or language barriers which could interfere with participation in the assessments. Participants were recruited from two private bariatric clinics in Perth, Western Australia. Approval was obtained from the relevant Human Research Ethics Committee (approval number HR 08/2013) and all participants provided written informed consent.

2.2 Recruitment and assessment protocol

When attending the bariatric surgery clinic for an initial appointment with the surgeon, potential participants were handed a form that asked if they agreed to be contacted by a researcher. They were also provided with a participant information sheet which described the study. Only those individuals who granted permission to be contacted were approached to participate in the study. Data were collected immediately prior to surgery and then at three, six, nine and 12 months post-surgery. At all time points, measures were collected of PA, ST, self-efficacy for exercise and weight. During the pre-surgery assessment only, age, sex and height were recorded. At both pre-surgery and 12 months post-surgery, measures were collected of body composition and cardiovascular fitness.

2.2.1 Physical activity and sedentary time

Participants were fitted with two wearable devices; the SenseWear Armband (SAB) (Body-Media Inc., Pittsburgh, PA, USA) and the StepWatch3 Activity Monitor (SAM) (Orthocare Innovation, Seattle, WA, USA). The devices were handed to participants in person at the pre- and 12-month post-surgery, and sent via mail at three, six, and nine months post-surgery appointments. They were instructed to wear these devices for seven days, removing them only when performing water activities (e.g. showering) and to engage in a typical week of activities. Both the SAB and SAM have been used in research with people who underwent bariatric surgery [10, 11, 20-22].

2.2.2 Self-efficacy for exercise

Self-efficacy for exercise was assessed using the Exercise Self-Efficacy Scale (ESES) [23]. This tool presents 18 scenarios for which participants are asked to rate their confidence in their ability to exercise on a scale that ranges from 0 (cannot do this activity at all) to 100 (highly certain that can do this activity) [23]. The ESES has been used in studies of people with overweight and obesity [24, 25].

2.2.3 Weight-related measures

Pre-surgery and 12 months post-surgery, weight was measured to the nearest 0.1 kg on a calibrated scale, with participants dressed in light clothing without shoes. At three, six, and nine months post-surgery, participants weighed themselves and reported the weight measured. Participants' BMI and percentage of excess weight loss (%EWL; based on an ideal body weight equivalent to a BMI of 25 kg/m^2) were also calculated.

2.2.4 Body composition

Body composition was assessed using whole-body dual energy x-ray absorptiometry (DXA) scanning (Lunar Prodigy, GE Healthcare, Diegem, Belgium) [26-28]. Measures were collected of fat mass (FM), %FM, fat-free mass (FFM), %FFM, and total, spine and pelvis bone mineral density (BMD), and total body BMD T-scores using proprietary software (encore v15 SP1, GE Healthcare, Shanghai, China).

2.2.5 Cardiovascular fitness

Cardiovascular fitness was assessed with the Physical Working Capacity 170 (PWC-170) test. This submaximal exercise test estimates the work capacity of a person at a heart rate of 170 bpm [29, 30]. The test was conducted on an electronically braked cycle ergometer (Lode Corival, Groningen, Netherlands) and comprised three stages, cycling at 60 revolutions per minute during the test. Each stage had a maximum duration of six minutes and was performed at increasing work rates with the aim of reaching target heart rates of 120, 135, and 150 bpm. Using linear regression, the relationship between heart rates and the three different work rates was used to extrapolate the work rate required to result in a heart rate of 170 bpm [31]. Submaximal exercise tests have been widely used to assess cardiovascular fitness, including in populations with obesity [29, 32, 33].

2.3 Data management and analyses

Statistical analyses were performed using Stata Statistical Software 13.1 for Windows (StataCorp LP, College Station, TX, USA). Data were expressed as mean (standard deviation [SD]) unless otherwise stated. Change between assessment time points was reported as mean change with 95% confidence intervals.

Participants’ data from the wearable devices were included in the analyses if they contributed a minimum of four days of data, with ≥12 hours/day of monitor wear time, including at least one weekend day [34, 35]. Using custom made software (LabVIEW 8.6.1; National Instruments, Austin, TX, USA), SAB postural data was used to remove overnight sleep time. Thereafter, the SAB data collected for each participant were interrogated using custom made exposure variation analysis (EVA) software (LabVIEW 8.6.1; National Instruments, Austin, TX, USA) [36, 37] and time was grouped according to intensities that corresponded to ST (<1.5 metabolic equivalents [METs]), light intensity PA (LIPA, 1.5 to <3 METs), and moderate-to-vigorous intensity PA (MVPA, ≥3 METs). Additionally, for each intensity, pattern of accumulation was determined by grouping epochs of uninterrupted time equivalent to 0 to <5 minutes, 5 to <10 minutes, 10 to <30 minutes, 30 to <60 minutes and ≥60 minutes. The EVA data were expressed as percentages of total average daily monitor wear time (i.e. waking hours).

Change in measures of PA, ST, self-efficacy for exercise and weight measured at all assessments was analyzed using multilevel, mixed-effects linear regression models. Time was modelled as a categorical variable, allowing separate estimates of change between all assessments. Data are presented as both the observed and predicted means. This approach allows the potential impact of the missing data on the results to be considered. *A priori* contrasts of interest for time were change from the preceding assessment, and total change from pre-surgery to 12 months post-surgery. Paired sample *t*-tests was used to compare body composition and cardiovascular fitness measures collected pre- and 12 months post-surgery.

Sample size was limited by feasibility, not dictated by the number needed to detect a particular effect. Calculations based on the pre-surgery daily step count reported by King et al. [1] and Langenberg et al. [6] indicated a feasible sample size of 30 participants would give a power of .96 to detect a 30% change in daily step count at α=.05, assuming a conservative correlation between pre- and post-surgery measures of 0.5.

3 Results

3.1 Participants

Between April 2013 and June 2014, a total of 279 people were screened, 180 (65%) were eligible and 36 agreed to participate. A participants' flowchart is provided in Figure 1. Characteristics of participants at the pre-surgery assessment are presented on Table 1. The average (SD) length of hospital stay was 2.1 (0.3) days and there were no reported peri-operative or early post-operative complications. One participant who underwent SG withdrew before completing the 9-month assessment.

3.2 Physical activity and sedentary time

Over the five assessments, the average (SD) number of days participants wore the SAB ranged between 5.6 (0.8) and 6.1 (1.1) days, with an average (SD) daily wear time ranging from 15.0 (1.0) and 16.3 (2.4) hours/day. The average (SD) number of days that participants wore the SAM ranged between 6.5 (0.8) and 6.6 (0.9) days.

There was no change in the percentage of waking hours spent in ST, LIPA, and MVPA, or in daily step count over the five assessments (Table 2). The pattern of accumulation for ST as well as time spent in LIPA and MVPA was unchanged over the five assessments (Table 3). As neither ST nor PA changed over 12 months post-surgery, no associations between these outcomes and change in weight, self-efficacy for exercise, body composition and cardiovascular fitness were tested.

3.3 Self-efficacy for exercise

Compared to pre-surgery, at 12 months post-surgery there was an increase in self-efficacy for exercise (mean change, 18.9; 95% CI, 11.3 to 26.5). The majority of change occurred in the first 3 months, and was maintained up to 12 months post-surgery (Table 4).

3.4 Weight-related measures

Compared to pre-surgery, at 12 months post-surgery there were decreases in weight (mean change, -27.9 kg; 95% CI, -31.4 to -24.5), BMI (mean change, -9.7 kg/m^2; 95% CI, -10.9 to -8.5), and %EWL (mean change, -72%; 95% CI, -83 to -61). The majority of change occurred in the first 3 months, with further smaller reductions to 12 months post-surgery (Table 4).

3.5 Body composition

Compared to pre-surgery, at 12 months post-surgery there was a decrease in FFM (mean change, -5.1 kg; 95% CI, -6.5 to -3.7), FM (mean change, -21.9 kg; 95% CI, -26.9 to -17.0), %FM (mean change, -10%; 95% CI, -13 to -8), and regional BMD of the spine (mean change, -0.08 g/cm^2; 95% CI, -0.12 to -0.04) and pelvis (mean change, -0.05 g/cm^2; 95% CI, -0.07 to -0.03) (Table 4).

3.5 Cardiovascular fitness

Compared to pre-surgery (mean, 194 W; SD, 64), at 12 months post-surgery (mean, 210 W; SD, 52) there was no change in the estimated load required to achieve a heart rate of 170 bpm in the PWC-170 (mean change, 16 W; 95% CI, -7 to 39) (Table 4).

4 Discussion

This study is the first to collect detailed device-based measures of PA and ST before and every three months up to 12 months post-surgery in adults undergoing primary bariatric surgery (i.e. LAGB or SG). Consistent with earlier data, our findings demonstrated large reductions in weight-related measures [38-40]. However, when compared to pre-surgery measures, there were no changes in ST and PA in the 12 months post-surgery. At all time points, participants spent most of their waking hours accumulating ST, with little time spent in LIPA and almost no time in MVPA. In keeping with the lack of change in MVPA, cardiovascular fitness was unchanged post-surgery [41, 42]. Perhaps paradoxically, our data demonstrated large and significant improvements in self-efficacy for exercise.

Although a lack of change in measures of PA over the first year post-surgery is generally consistent with earlier research [9, 14, 43], this study extends previous work by providing robust data on both ST and PA at different intensities, including data on how time in these constructs was accumulated over multiple time points during the first 12 months post-surgery. It highlights the importance of targeting changes in both ST and PA as separate lifestyle goals. Although the health benefits of participating in MVPA are well accepted and, in people following bariatric surgery, increasing MVPA may assist with minimizing weight regain [44-47], there is increasing recognition of the cardiometabolic risk associated with ST. This risk is especially pronounced when ST is accumulated in prolonged uninterrupted periods [48, 49]. This point is relevant to this population who, at all assessments, spent over 70% of their waking hours in ST, and accumulated the vast majority of ST in bouts ≥30 minutes. In Australian adults with overweight, time in LIPA shows an almost perfect inverse relationship with ST [50], suggesting that initially targeting reductions in ST, through increased participation in LIPA, rather than MVPA, may be a more pragmatic and realistic option. Of note, in people with obesity, interventions that aim to reduce ST have produced concurrent improvements in the time spent in LIPA and MVPA [51, 52].

The improvement in self-efficacy for exercise, an important determinant of change in PA behavior [53], was surprising when device-based measures of PA and ST were unchanged.

This finding suggests that factors other than participation in PA, such as greater ease of movement, may have led to participants perceiving they were more able to engage in PA post-surgery. Our group has shown that, post-surgery, people reported feeling more able to engage in everyday tasks as a result of a reduction in obesity-related physical limitations [54]. As both weight loss and improvement in self-efficacy for exercise plateaued at six months post-surgery, it would seem prudent at this time point to consider introducing additional strategies such as facilitating mastery experiences and social modelling to maximize the likelihood of increasing participation in PA and reducing ST. Specific behavioral change techniques that target motivation[55] as well as action and coping planning may be useful as these have produced short-term improvements in device-based measures of MVPA in bariatric surgery candidates [21].

Clinical implications and future directions

This study has demonstrated that pre-surgery measures of ST and PA, and the way time in these domains were accumulated, were unchanged in the first 12 months following bariatric surgery. When compared to measures collected in the general adult population, at 12 months post-surgery, our study sample had a somewhat lower average daily step count (8,871 versus 9,676 steps/day) and accumulated more ST during waking hours (73% versus 56% of waking hours) [56, 57]. As participation in low levels of PA is an important contributing factor to weight regain post-surgery [44-47], our study highlights the need to explore strategies that target increased participation in PA and a reduction in ST in this population. This may include trialing the involvement of a multi-disciplinary team during the post-operative period to address non-weight related barriers to participation in PA such as management of lower limb osteoarthritis and specific behavior change techniques that have been successful at increasing PA in people prior to bariatric surgery, such as problem solving, goal setting, self-monitoring of behavior, and commitment to behavior change [21, 55, 58, 59].

Data reported in this study can be used as a basis to develop the more granular details of a behavior change intervention in this population. That is, as this study demonstrated that PA was most commonly performed at a light intensity rather than moderate to vigorous intensity, targeting an increase in light intensity PA, as an initial step, may assist with both reducing ST and also serve as a gateway to increased participation in MVPA. Behavioural interventions are more likely to produce greater effects when they initially target feasible changes in PA [58-61]. This is because promoting feasible changes and achievable goals are more likely to increase people's self-efficacy to progress to more challenging activities. The favourable influence of increasing participation in light intensity activity on cardiometabolic health is now well-recognised [50, 62, 63]. Further, the majority of weight loss and gains in self-efficacy for exercise occurred in the first 3 to 6 months following surgery, with less or no change seen after this time point. This suggests that the optimal time to commence a behavior change intervention which targets PA and ST may be 6 months post-surgery, when the majority of weight loss and gains in self-efficacy for exercise, have occurred.

Strengths and limitations

The main strength of this study is the utilization of wearable devices to measure ST and PA, at different intensities, at multiple time points over the first 12 months post-surgery. Other strengths include the investigation of changes in self-efficacy for exercise, body composition and cardiovascular fitness. Finally, for most outcome measures collected in this study there was minimal loss to follow-up, and the use of multiple time points combined with multilevel mixed effects model limited bias of estimates at assessment time points with missing data.

Limitations include a sample comprised of private practice clients, which may limit the generalizability of the findings to people in the public health system. Although the sample size was limited by feasibility considerations, power calculations confirmed 30 participants was sufficient to detect important changes in the primary outcomes. The lack of changes in measures of PA and ST precluded the investigation of associations between the magnitude of these changes with the magnitude of change in weight, self-efficacy for exercise, body composition and cardiovascular fitness. Additionally, a large number of eligible participants were unwilling to participate in the study, which may also affect the generalizability of findings.

Conclusion

This study demonstrated no change in device-based measures of PA, ST or cardiovascular fitness following bariatric surgery (i.e. LAGB or SG), despite substantial weight loss, as well as improvements in self-efficacy for exercise. This findings suggest that although bariatric surgery results in significant weight loss, by itself it was not sufficient to effect change in PA, at any intensity, or ST. Complementing surgical intervention with behavioral interventions may optimize change in PA and ST.

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

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