School of Physiotherapy and Exercise Science

Physical Activity, Sedentary Behaviour and Other Health Outcomes in People Following Restrictive Bariatric Surgery

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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STATEMENT OF ORIGINALITY

This thesis is presented for the degree of Doctor of Philosophy at Curtin University Western Australia. Studies were undertaken between January 2013 and August 2015, through the School of Physiotherapy and Exercise Science at Curtin University.

This research project was developed in association with my supervisors who have been involved in editing both this thesis and all associated publications. All material presented in this thesis is original.

ABSTRACT

Background

Restrictive bariatric procedures have been increasingly used to manage obesity in Western countries (1). Despite the substantial weight loss and improvement in several health outcomes seen following bariatric surgery (2, 3), there is evidence to suggest little or no change in objective measures of physical activity (PA) and sedentary behaviour (SB) (4-9). However, the studies that investigated pre- to post-surgery changes in objective measures of PA and SB had important limitations in regards to the assessment methods used, including low adherence to the motion sensor used (4), and suboptimal placement of the motion sensor around the waist or hip, which might decrease accuracy due to motion sensor tilt as a result of abdominal adipose tissue (5, 8). Additionally, the samples in these studies contained mostly people who underwent gastric bypass, which may limit the generalisability of their findings to people who undergo restrictive bariatric surgery. Therefore, there is a need for studies that use state-of-the-art devices to investigate changes in objective measures of PA and SB following restrictive bariatric surgery. If, following surgery, people do not change their PA and SB, they remain at risk of the detrimental effects of participation in little PA and increased SB, regardless of the amount of weight loss achieved post-surgery. Little is known about outcomes relevant to participation in PA among people who undergo restrictive bariatric surgery, such as self-efficacy to exercise, cardiovascular fitness, sleep quality, daytime sleepiness, body composition and bone mineral density (BMD). Further, there are scarce data on the reasons why people scheduled to undergo restrictive bariatric surgery engage in low levels of PA or why this behaviour appears to persist despite significant post-surgery weight loss. A better understanding of the effect of surgery on outcomes relevant to PA, and of factors that influence participation in PA, such as beliefs about PA, perceived barriers and facilitators to PA among people who undergo restrictive bariatric surgery, and how they change post-surgery, is needed to shape behavioural interventions aimed at increasing PA in this population (10, 11). Although the favourable effects of bariatric surgery on measures of weight, health-related quality of life (HRQoL) and symptoms of mental health disorders are well-documented following surgery, little is known regarding the pattern of change in these outcomes over the first 12 months following bariatric surgery, when the majority of weight loss is expected to happen. The investigation of the pattern of

change in different outcomes post-surgery could provide useful data to inform patients' expectations and post-surgery management (12-15).

This programme of research comprised two studies. Study 1 was a quantitative, longitudinal study that investigated changes in the primary outcome measures of PA and SB, and in secondary outcome measures. First, changes were investigated in secondary outcomes that have not been widely investigated in previous literature and are relevant to PA. Second, changes were investigated in secondary outcomes that have been widely investigate, in order to confirm the previously established efficacy of restrictive bariatric surgery procedures and ensure that the investigation of measures of PA and SB occurred in the context of the expected response to surgery. Further, for the primary outcomes, and when feasible, for secondary outcomes, measures were collected pre-surgery and every 3 months for the first 12 months post-surgery, in order to investigate the magnitude and pattern of change following restrictive bariatric surgery. Study 2 was a qualitative, longitudinal study in a separate sample to Study 1 that explored participants' perceptions of factors related to their participation in PA pre-surgery and 12 months post-surgery, and how these differed from their pre-surgery perceptions. Study 2 was divided in two parts: Study 2(A) was conducted prior to restrictive bariatric surgery and Study 2(B) at 12 months following restrictive bariatric surgery. Both Study 2(A) and (B) were conducted in the same sample of participants.

Study 1 – Physical activity, sedentary behaviour and other health outcomes following restrictive bariatric surgery

The following research questions were addressed in Study 1:

(i) Compared with measures collected pre-surgery, what is the magnitude of change in measures of PA and SB collected over the first 12 months following restrictive bariatric surgery?

(ii) Compared with measures collected pre-surgery, what is the magnitude of change in measures of cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, body composition and BMD, collected over the first 12 months following restrictive bariatric surgery?

(iii) Compared with measures collected pre-surgery, what is the magnitude of change in measures of weight, obesity-related comorbid conditions, HRQoL,

obesity-related quality of life and weight-related symptoms, and symptoms of depression, anxiety and stress; and (iv) does the magnitude of change in measures of weight differ between laparoscopic sleeve gastrectomy (LSG) in comparison to laparoscopic adjustable gastric banding (LAGB) over the first 12 months following restrictive bariatric surgery ?

Methods: Obese adults who were scheduled to undergo restrictive bariatric surgery were assessed pre-surgery and every 3 months for the first 12 months post-surgery. Pre-surgery and at 12 months post-surgery, measurements were collected of PA and SB, using the SenseWear Armband (SAB) and the StepWatch 3 Activity Monitor (SAM). Energy expenditure, expressed as METs, derived from the SAB, were used to group time spent in SB and PA at different intensities. Specifically, each minute of waking hours was grouped into the following categories; SB (i.e. < 1.5 METs), light intensity PA (i.e. 1.5 to < 3 METs), and moderate to vigorous intensity PA (≥ 3 METs). Data from the SAM provided measures of daily step count. Measures were also collected of cardiovascular fitness (Physical Working Capacity 170 test), self-efficacy to exercise (Exercise Self-Efficacy Scale), sleep quality (Pittsburgh Sleep Quality Index), daytime sleepiness (Epworth Sleepiness Scale), body composition and BMD (whole-body dual energy x-ray absorptiometry), weight (scale), obesity-related comorbid conditions (blood samples and ApneaLink), HRQoL (Medical Outcomes Study Short Form 12 General Health Survey v2), obesity-related quality of life and weight-related symptoms (Impact of Weight on Quality of Life Questionnaire, Obesity and Weight-loss Quality-of-life Instrument, and Weight-related Symptoms Measure), and symptoms of depression, anxiety and stress (Beck Depression Inventory and Depression Anxiety Stress Scales). Additionally, at 3, 6 and 9 months post-surgery, measures were collected of all outcomes except cardiovascular fitness, body composition and BMD, and obesity-related comorbid conditions.

Results: Thirty obese adults (20 females) participated in this study, with a mean age of 44.1 years (standard deviation [SD], 11.2), weight of 114.6 kg (SD, 17.2), and body mass index (BMI) of 39.6 kg/m^2 (SD, 5.5). Twenty two (73%) participants underwent LSG and eight (27%) underwent LAGB. Compared to pre-surgery measures, 12 months post-surgery there were no changes in measures of SB (mean change, -2% waking hours; 95% confidence interval [CI], -6 to 3), light intensity PA (mean change, 1% waking hours; 95% CI, -3 to 5), or moderate to vigorous intensity PA (MVPA; mean change, 1% waking hours; 95% CI, -1 to 3). At

all time points, participants spent more than 70% of their waking hours in SB, which was mostly accumulated in prolonged uninterrupted bouts ≥ 30 minutes (i.e. ≥ 51% of total time in SB), and only 5% of their waking hours in MVPA, which was mostly accumulated in very short bouts < 10 minutes (i.e. ≥ 82% of total time in MVPA). Additionally, the little time participants spent in PA was mostly performed in light intensity (i.e. around 20% of waking hours). There was also no change in participants' daily step count or cardiovascular fitness. The lack of change in measures of PA, SB and cardiovascular fitness occurred despite a significant improvement in participants' self-efficacy to exercise (mean change, 18.9 points; 95% CI, 11.3 to 26.5) and large and significant reductions in weight-related measures (mean change, 72% of excess weight loss; 95% CI, 61 to 83). Similarly, there were large and significant improvements in measures of sleep quality, daytime sleepiness, HRQoL, obesity-related quality of life and weight-related symptoms and symptoms of depression, anxiety and stress. The substantial weight loss achieved post-surgery was accompanied by reductions in fat mass (mean change, -21.9 kg; 95% CI, -26.9 to -17.0) and fat-free mass (mean change, -5.1 kg; 95% CI, -6.5 to -3.7), with no change in total body BMD. The majority of change in significantly improved outcomes was observed in the first 3 months, with less or no change between 6 and 12 months post-surgery.

Study 2 – Qualitative exploration of factors related to participation in physical activity among people prior to and 12 months following restrictive bariatric surgery

The following research questions were addressed in Study 2:

(i) Prior to restrictive bariatric surgery, what are participants' beliefs about PA, and perceived barriers and facilitators to PA?

(ii) Twelve months following restrictive bariatric surgery, (a) what are the perceptions of participants regarding their ability to participate in PA as well as barriers and facilitators to PA? (b) How do these perceptions differ from participants' perceptions pre-surgery? and (c) What are the perceived motivators to PA at 12 months following restrictive bariatric surgery?

Methods: Study 2(A): obese adults participated in a semi-structured one-on-one interview within the month immediately prior to restrictive bariatric surgery. Study

2(B): participants from Study 2(A) were invited to participate in semi-structured one-on-one interviews 12 months following restrictive bariatric surgery. The interviews comprised open-ended questions focused on participants' beliefs about PA, perceived barriers and facilitators to PA, perceived ability to engage in PA and perceived motivators to PA. All interviews were audio-recorded and transcribed verbatim. Data were analysed using thematic analysis and emergent themes were reported with supporting quotes.

Results: Study 2(A): 19 obese adults (15 females) were interviewed pre-surgery, with a mean age of 41.6 years (range, 19 - 66), weight of 119.2 kg (range, 92.8 - 182.2), and BMI of 41.6 kg/m^2 (range, 30.0 - 54.2). Although most participants believed that engaging in regular PA was important for health benefits, they reported participating in insufficient PA levels to obtain those benefits. The perceived barriers to PA were both obesity-related (e.g. bodily pain, physical limitation, and self-presentational concerns) and non-obesity related (e.g. lack of motivation, lack of time and social support issues). All participants reported weight loss as the main perceived facilitator to PA, together with social factors, better time management, and access to financial resources. Study 2(B): 14 (12 females) of the 19 participants from Study 2(A) were interviewed at 12 months post-surgery. Eight (57%) participants underwent LSG and six (43%) underwent LAGB. At this post-surgery interview, their mean weight was 90.3 kg (range, 60.0 - 152.0), BMI was 31.7 kg/m^2 (range, 22.3 - 48.2), and average percentage of excess weight loss was 66% (range, 2 - 127). Most participants indicated not engaging in PA during the first 3 to 6 months post-surgery, and many reported no change or decreased participation in PA over the first 12 months post-surgery. Participants reported an increase in their ability to engage in PA, which was mostly described as a result of the reduction in obesity-related physical barriers to PA achieved with weight loss, such as bodily pain and extra physical work. Despite the reports of improvements in some obesity-related barriers to PA (e.g. physical barriers and self-presentational concerns), many participants indicated that there were residual obesity-related perceived barriers to PA (e.g. joint pain) and for some there was a shift in focus regarding self-presentational concerns from pre-surgery to 12 months post-surgery (i.e. from excess weight to excess skin). Most participants reported that the non-obesity related perceived barriers to PA identified pre-surgery, such as lack of motivation, lack of time and social support issues, were still present at 12 months post-surgery. Participants reported low motivation to engage in PA, and believed PA to be unnecessary post-surgery given the substantial weight loss achieved. Perceived

facilitators to PA were consistent between pre- and post-surgery interviews. Regarding motivators to PA, at 12 months post-surgery, extrinsic, esteem-based motivators, such as additional weight loss and improving physical appearance were the most commonly reported.

Discussion and conclusions

Study 1 demonstrated that, when compared with pre-surgery measures, there were no changes in total time spent in PA, at any intensity, in total time spent in SB, or in the way PA and SB were accumulated over the first 12 months following restrictive bariatric surgery. There was also no change in cardiovascular fitness. The lack of change in measures of PA, SB and cardiovascular fitness occurred despite large and significant weight loss and improvement in self-efficacy to exercise. These findings also strongly suggest that large and significant improvements in sleep quality, daytime sleepiness, HRQoL, obesity-related quality of life and weight-related symptoms and symptoms of mental health disorders do not result in enhanced participation in PA and SB. The lack of change in PA despite improvements in self-efficacy to exercise and other health outcomes (e.g. weight-related symptoms) was supported by findings from Study 2, which demonstrated most participants did not change their participation in PA over the first 12 months post-surgery despite reports of an increase in their ability to engage in PA and of reductions in obesity-related barriers to PA. Findings from Study 2 also indicated the presence of several residual perceived barriers to PA, particularly non-obesity related barriers, such as lack of motivation, lack of time and social support issues at 12 months post-surgery. Particularly, at 12 months post-surgery, participants presented mainly extrinsic or controlled types of motivation, such as additional weight loss and improvement in physical appearance, rather than intrinsic or self-determined types of motivation, such as enjoyment of PA. This is important given extrinsic types of motivation have little association with maintenance of PA (16, 17).

The findings from this programme of research provide novel insight into factors relevant to participation in PA in people following restrictive bariatric surgery, and highlights that a behavioural intervention with a multidisciplinary approach is likely to be required in order to change PA in this population. Further, these findings demonstrated that the little time people spent in PA was mostly performed in light intensity PA rather than MVPA. Therefore, a behavioural intervention should include goal setting strategies that target feasible goals for increasing PA, such as an initial increase in light intensity PA, which would likely further improve people's self-efficacy to engage in PA and serve as a gateway to both reduce time spent in SB and increase participation in more challenging activities (i.e. MVPA). Such an intervention could also be enhanced by including a combination of problem solving and planning strategies to manage the several barriers to PA identified both pre- and post-surgery. Further, the use of strategies aimed at reducing extrinsic types of motivation and promoting intrinsic types of motivation in such an intervention is likely to enhance the efficacy of such interventions. Future research is needed in people following restrictive bariatric surgery to investigate the effect of a multidisciplinary behavioural intervention aimed at optimising PA on significant and sustained changes in PA, as well as other relevant outcomes, such as reduced cardiometabolic risk and weight maintenance. Such an intervention should target goal setting, problem solving and planning strategies, as well as self-efficacy and motivation to engage in PA.

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%EWL	percentage of excess weight loss
AHI	apnoea-hypopnoea index
BDI	Beck Depression Inventory
BIA	bioelectrical impedance analysis
BMD	bone mineral density
BMI	body mass index
CI(s)	confidence interval(s)
cm	centimetres
CVD	cardiovascular disease
DASS-21	Depression Anxiety Stress Scales
DM2	diabetes mellitus type 2
DXA	whole-body dual energy x-ray absorptiometry
ESES	Exercise Self-Efficacy Scale
ESS	Epworth Sleepiness Scale
FFM	fat-free mass
FM	fat mass
g/cm^2	gram(s) per centimetres square
HRQoL	health-related quality of life
IQR	inter-quartile range
IRR(s)	incidence rate ratio(s)
IWQOL-Lite	short version of the Impact of Weight on Quality of Life Questionnaire
JZ	Juliana Zabatiero
kg	kilogram(s)
kg/m^2	kilogram(s) per metres squared
L	litres
LAGB	laparoscopic adjustable gastric banding

LBM	lean body mass
LSG	laparoscopic sleeve gastrectomy
MCS	mental component summary
METs	metabolic equivalent units
mg/dL	milligrams per decilitre
min	minute(s)
mL	millilitre(s)
mmHg	millimetre of mercury
mmol/L	millimoles per litre
MVPA	moderate to vigorous intensity physical activity
n	number of participants
OSA	obstructive sleep apnoea
OWLQOL	Obesity and Weight-loss Quality-of-life Instrument
PA	physical activity
PCS	physical component summary
PSQI	Pittsburgh Sleep Quality Index
PWC-170	Physical Working Capacity 170 test
RCT(s)	randomised controlled trial(s)
RYGB	*Roux-en-Y* gastric bypass
SAB	SenseWear Armband
SAM	Stepwatch 3 Activity Monitor
SB	sedentary behaviour
SD	standard deviation
SF-12v2	Medical Outcomes Study Short Form 12 General Health Survey version 2
SF-36	Medical Outcomes Study Short Form 36 General Health Survey
SpO_2	arterial oxygen saturation measured via pulse oximetry
USA	United States of America

W	watts
WRSM	Weight-related Symptoms Measure

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PUBLICATIONS ARISING FROM THIS THESIS

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Manuscripts in preparation

Zabatiero, J, Smith A, Gucciardi DF, Hagger MS, Hamdorf, JM, Taylor SF, Hill K. Physical activity, sedentary behaviour and associated health outcomes before and after restrictive bariatric surgery.

Zabatiero, J, Hill K, Gucciardi DF, Hamdorf, JM, Taylor SF, Hagger MS, Smith A. Barriers, facilitators and motivators to physical activity 12 months following restrictive bariatric surgery: a longitudinal qualitative exploration.

CONFERENCE PRESENTATIONS

2014

Australian and New Zealand Obesity Society's Annual Scientific Meeting - Sidney, New South Wales, Australia

Title: **Patterns of sedentary behaviour and physical activity before and three months after bariatric surgery.** (Poster presentation)

Title: **Barriers and facilitators to physical activity in adults before bariatric surgery.** (Poster presentation)

Curtin University's Mark Liveris Seminar - Perth, Western Australia, Australia

Title: **Patterns of sedentary behaviour and physical activity before and three months after bariatric surgery.** (Oral presentation)

AWARDS

Data collection grant - Curtin University Postgraduate Student Association (CUPSA)

Awarded in 2014 for a successful application for a PhD data collection grant.

Best paper presenter - Curtin University's Mark Liveris Seminar

Awarded at the Mark Liveris Seminar in 2014 for best paper presenter.

CHAPTER 1 INTRODUCTION

Overview

Obesity has become a major health problem, and is currently considered one of the most important causes of preventable death worldwide (18). The prevalence of obesity has increased rapidly, with the most recent population-based data from Australia indicating that 63% of adults were overweight or obese in 2011-2012, which represented a 7% increase from 1995 (19). Surgical treatment, also referred to as bariatric surgery, has been increasingly used to manage obesity in Western countries (1). This increase is because when compared to non-surgical treatment options (e.g. diet, exercise, lifestyle interventions), surgical treatment results in greater and sustained weight loss, as well as improvement and/or resolution of obesity-related comorbid conditions (2, 3).

Despite the effectiveness of bariatric surgery for the treatment of obesity, there is evidence to show that, both pre- and post-surgery, people participate in little physical activity (PA) and spend most of their waking hours in sedentary behaviour (SB) (20-29). The few studies that have collected objective measures of PA and SB data in people pre- and post-surgery often report little or no change in these measures (4-9). However, these studies presented important limitations regarding methods used to assess PA and SB. Specifically, these limitations included low adherence to the motion sensor used (4), and suboptimal placement of the motion sensor around the waist or hip, which might decrease accuracy due to motion sensor tilt as a result of abdominal adipose tissue (5, 8). If, following bariatric surgery, people do not increase their participation in PA and reduce time spent in SB, they are still at risk of the detrimental health effects associated with a pattern of little participation in PA and increased SB, regardless of the significant weight loss and improvement and/or resolution of obesity-related comorbid conditions achieved post-surgery (30-33). Given the increased use of bariatric surgery for the treatment of obesity, particularly of restrictive procedures, there is a need for studies which use state-of-the-art devices to investigate pre- to post-surgery changes in objective measures of PA and SB.

There is a growing interest in the possible beneficial effects of adding behavioural interventions that target an increase in PA, pre- or post-surgery, on bariatric surgery outcomes (34-38). However, little is known about outcomes relevant to participation in PA among people who undergo restrictive bariatric surgery, such as self-efficacy to exercise, cardiovascular fitness, sleep quality, daytime sleepiness, body composition and bone mineral density (BMD). Additionally, there are scarce data on people's perceptions of barriers, facilitators and motivators to PA in this population. A comprehensive understanding of factors that influence participation in PA among people who undergo restrictive bariatric surgery, and how they change post-surgery, is needed to shape behavioural interventions aimed at increasing PA in this population (10, 11).

Furthermore, although beneficial changes in a number of outcomes, including measures of weight, health-related quality of life (HRQoL) and symptoms of mental health disorders are well-documented following bariatric surgery, little is known regarding the pattern of change in these outcomes over the first 12 months post-surgery, when the majority of weight loss is expected to happen. The assessment of the pattern of change, that is, the investigation of the time over which most of the change in different outcomes occurs for the average patient during the first 12 months post-surgery is relevant to inform both patients' expectations and post-surgical management (12-15).

This programme of research investigated changes in measures of PA, SB, and other health outcomes relevant to participation in PA over the first 12 months following restrictive bariatric surgery. Additionally, in a separate sample, it explored participants' perceptions of factors related to their participation in PA pre-surgery and how these changed post-surgery. This chapter provides an overview of the literature related to the development of the research questions addressed by the two studies that comprised this programme of research. The significance of the programme of research is also discussed.

1.1 Study 1

The first study in this programme of research investigated changes in measures of PA, SB, and other health outcomes following restrictive bariatric surgery. The primary outcome measures of PA and SB were collected pre-surgery and every 3 months for the first 12 months post-surgery. Secondary outcome measures were divided in two groups. First, measures were collected of outcomes that have not been widely investigated in previous literature and are relevant to participation in PA. These measures comprised cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, body composition and BMD. Second, measures were collected to confirm the previously established efficacy of restrictive bariatric surgery procedures, to ensure that the investigation of measures of PA and SB occurred in the context of the expected response to surgery. These measures comprised weight, obesity-related comorbid conditions, HRQoL, obesity-related quality of life and weight-related symptoms, and symptoms of depression, anxiety and stress. When feasible, secondary outcome measures were also collected at multiple time points over the first 12 months post-surgery, in order to investigate the magnitude and pattern of change post-surgery.

1.1.1 Primary research question

Compared with measures collected pre-surgery, what is the magnitude of change in measures of PA and SB collected over the first 12 months following restrictive bariatric surgery?

1.1.1.1 Background

People who are obese and those scheduled to undergo bariatric surgery participate in little PA and spend most of their time in SB (20-24, 27, 39, 40). There are also data to suggest that people scheduled to undergo bariatric surgery have lower participation in PA and spend more time in SB than the general population (21, 41). This is of concern since regular participation in PA, particularly moderate to vigorous intensity PA (MVPA), has been associated with several physical and mental health benefits, such as lower risk of obesity-related comorbid conditions (e.g. diabetes mellitus type 2 [DM2] and cardiovascular diseases), symptoms of mental health disorders, and all-cause and disease-specific mortality (42). Further, research has shown that increased time spent in SB results in deleterious health effects, regardless of participation in MVPA (43-45). More recently, there is evidence to show beneficial effects on cardiometabolic health when time spent in SB is replaced by light intensity PA (46-49). In addition to the total amount of time spent in PA and SB, the way in which PA and SB are accumulated is also relevant to health effects (43, 50). International guidelines for the development and maintenance of health recommend that, in order to optimise the health benefits related to PA, adults should participate in a minimum of 150 minutes of MVPA per week, and that MVPA should be accumulated in bouts of at least 10 minutes (50). In order to prevent weight gain, recent guidelines recommend that adults should accumulate between 150 and 250 minutes of MVPA per week, with greater amounts (>250 minutes of MVPA per week) needed for weight loss (51). Additionally, data from recent research recommend people to interrupt prolonged continuous periods of SB (i.e. > 30 minutes) as often as possible, which can be done with light intensity PA (e.g. standing, slow walking) (52-54).

It might be reasonable to expect that following bariatric surgery, the dramatic weight loss would facilitate greater participation in PA and decreased time in SB. Nevertheless, the few studies that have investigated pre- to post-surgery changes in objective measures of PA and SB suggest little or no change in such measures (4-9). However, the results of these studies may be limited by factors related to the assessment of PA and SB, including low adherence to the motion sensor used (i.e. only 37% of participants with valid motion sensor data) (4), and suboptimal placement of the motion sensor around the waist or hip, which might decrease accuracy due to motion sensor tilt as a result of abdominal adipose tissue (5, 8). Further, these studies focused on measures of MVPA and daily step count, with only two studies reporting time spent in SB (7, 8) and no study reporting time spent in light intensity PA. Additionally, the samples in these studies were comprised mostly of people who underwent gastric bypass, which may limit the generalisability of their findings to people who undergo restrictive bariatric surgery. This is because malabsorptive and mixed bariatric procedures have been found to result in longer hospital stay, higher rates of post-surgery complications and of nutritional deficiencies that may affect post-surgery recovery, energy levels, and participation in PA (3, 55, 56).

Understanding the effect of bariatric surgery on PA and SB is important. This is because the health benefits of participation in PA and the detrimental health effects of SB are independent of obesity (43-45, 57-65). That is, despite large weight loss post-surgery, if people do not change their PA and SB, they remain at risk of the detrimental effects of participation in little PA and increased time spent in SB. Furthermore, specific to this population, participation in the recommended amounts of MVPA and decreased time spent in SB have been associated with better post-surgery outcomes, such as greater weight loss, favourable changes in body composition and risk factors of cardiovascular disease, and better HRQoL (66-69). This study will extend the current understanding of the effect of restrictive bariatric surgery on PA and SB by reporting changes at multiple time points over the first 12 months post-surgery, and how time in PA and SB is accumulated. This is important since not just total time spent in PA and SB, but also the way in which they are accumulated is important to health effects (43, 50, 54, 70). Finally, this study will report on changes across the activity spectrum, including light intensity PA. This is of relevance given the increasing recognition of the cardiometabolic health benefits associated with participation in light intensity PA (46-49).Therefore, in this population, detailed analyses that characterise PA, at any intensity, and SB pre-surgery and over the first 12 months post-surgery will provide useful information on which to shape future behavioural interventions that aim to optimise total time in PA and SB and/or the way in which time in PA and SB are accumulated. Such interventions may enhance other post-surgery outcomes.

1.1.2 Secondary research question (outcomes relevant to physical activity)

Compared with measures collected pre-surgery, what is the magnitude of change in measures of cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, body composition and BMD, collected over the first 12 months following restrictive bariatric surgery?

1.1.2.1 Background

In people who undergo bariatric surgery, little attention has been given to factors that may influence, or be influenced by, participation in PA. Specifically, people who are overweight and obese often report that starting and adhering to planned and structured PA poses a daunting challenge. This population also often reports negative experiences regarding participation in PA (71, 72). They are therefore likely to have low self-efficacy to engage in PA, which is defined as the belief that one has the ability to successfully engage in PA (73). To date, no study has investigated the effect of restrictive bariatric surgery on self-efficacy, which is surprising given that self-efficacy to exercise has been recognised as an important determinant of change in PA (74). Following bariatric surgery, the dramatic weight loss may serve to improve people's self-efficacy to exercise. As self-efficacy can be changed and developed through behavioural interventions (75), understanding whether or not bariatric surgery improves self-efficacy to exercise may inform clinicians of whether self-efficacy to exercise should be targeted in this population. Further, information regarding timing of any such change during the first 12 months post-surgery may be useful when determining the optimal time for an intervention that aims to increase participation in PA among people following bariatric surgery.

One important factor that may limit participation in MVPA among people scheduled for bariatric surgery is impaired cardiovascular fitness. That is, people who are obese and have low cardiovascular fitness may lack the capacity to engage in MVPA (76-80). Reductions in aerobic reserve may explain earlier reports of people who are overweight or obese perceiving MVPA as more laborious and less pleasant than their normal-weight counterparts (71, 72, 81). This, in turn, is likely to compromise their participation in MVPA. There are scarce data on pre- to post-surgery changes in measures of cardiovascular fitness following restrictive bariatric surgery. Measures have been made using either a maximal or submaximal exercise test, and changes in cardiovascular fitness reported between 7 to 36 months post-surgery have been inconsistent (82-85). Although two studies have found a significant increase in measures of cardiovascular fitness (i.e. six-minute walk distance and resting heart rate) at 12 months following LAGB (82) and 3 years following RYGB and LAGB (85), the other two studies have found no change in measures of cardiovascular fitness (i.e. six-minute walk distance and peak oxygen uptake) at 7 months following LSG (84) and 28 months following RYGB and LSG (83).The inconsistent results might be explained by the different sample sizes (e.g. range of 15 to 1,205 participants per study), heterogeneous samples included in the studies, different assessment methods used and diverse follow-up periods. In addition, the aforementioned studies used either a maximal exercise test that may be influenced by people's ability and/or willingness to exercise until exhaustion, or a submaximal test that required walking, in which performance may be limited by gait limitations often found in the obese population (86). There are no studies that have investigated pre- to post-surgery changes in cardiovascular fitness using an exercise test that does not require maximal effort and is minimally affected by gait limitations, such as a submaximal exercise cycle test. Understanding the effect of restrictive bariatric surgery on cardiovascular fitness will inform clinicians about whether or not people's capacity to engage in MVPA improves post-surgery and whether an increase in cardiovascular fitness should be targeted as part of post-surgery management.

In addition to low cardiovascular fitness, it is possible that participation in PA is compromised by problems related to sleep, such as sleep disordered breathing (i.e. obstructive sleep apnoea), poor sleep quality and excessive daytime sleepiness. A high prevalence of such problems has been well established in people who are obese (87-89). The low energy levels and high levels of fatigue reported by people who experience problems with sleep are likely to have a negative influence on participation in PA (90). This is supported by findings from recent research showing that poor sleep predicts lower levels of PA (91, 92). Additionally, there is evidence to show that regular participation in PA results in better sleep (90). Little is known about the effect of restrictive bariatric surgery on measures of sleep quality and daytime sleepiness (93-98). The two studies that have investigated pre- to post-surgery changes in measures of sleep quality have reported significant improvements following restrictive bariatric surgery, however, only one of the two studies used a validated outcome measure (93, 96). The few studies that investigated pre- to post-surgery changes in measures of daytime sleepiness reported significant improvements following restrictive bariatric surgery (93-95, 97, 98). However, these studies focused exclusively on people who had severe obstructive sleep apnoea, which limits the generalisability of their findings to the wider population of people who undergo bariatric surgery.

Regarding factors that may be influenced by participation in PA, this programme of research also explored the effect of restrictive bariatric surgery on measures of body composition and BMD, using whole-body dual energy x-ray absorptiometry (DXA). Previous investigations of changes in measures of body composition following restrictive bariatric surgery have typically used bioelectrical impedance analysis (BIA) due to low cost and ease of application. However, measures of BIA are known to have considerable error in obese populations, and those studies which have used DXA have focused exclusively on people who underwent laparoscopic adjustable gastric banding and were limited to female samples (99-104). Previous research using DXA has consistently reported large and significant reductions in fat mass up to 2.5 years following restrictive bariatric surgery (100, 102-112). Of note, however, is that significant reductions in fat free mass up to 2 years have also been reported following restrictive bariatric surgery (100, 102-104, 106-108, 110-113). This is an undesirable outcome of surgery since decreased muscle mass, which is a component of fat-free mass, has been associated with limited mobility and increased risk of falls, particularly among older adults (114, 115). There are also data to suggest that the substantial weight loss achieved following restrictive bariatric surgery may reduce BMD, particularly regional measures of BMD (e.g. hip and spine) (99, 101, 104, 105, 112, 116-118). This information is relevant to assist clinicians with providing appropriate advice on the type of PA or exercise that should be adopted by people who undergo bariatric surgery. For example, participation in weight-bearing activities and resistance training is likely to prevent the loss of muscle and bone mass that may occur during the period of rapid weight loss post-surgery (119).

1.1.3 Secondary research questions (outcomes used to confirm the previously established efficacy of restrictive bariatric procedures)

Compared with measures collected pre-surgery, what is the magnitude of change in measures of weight, obesity-related comorbid conditions, HRQoL, obesity-related quality of life and weight-related symptoms, and symptoms of depression, anxiety and stress; and (iv) does the magnitude of change in measures of weight differ between laparoscopic sleeve gastrectomy (LSG) in comparison to laparoscopic adjustable gastric banding (LAGB) over the first 12 months following restrictive bariatric surgery?

1.1.3.1 Background

The main goal of obesity treatment is to achieve a substantial reduction in body weight that is maintained in the long term (2, 3). When compared to non-surgical interventions (e.g. diet, exercise, lifestyle interventions), bariatric surgery, regardless of the type of surgical procedure used, has been considered the most effective approach for the treatment of obesity as it provides greater and sustained weight loss (2, 3). The most recent worldwide survey of bariatric surgery has shown that in the Asia/Pacific region, which includes Australia, restrictive bariatric procedures (e.g. LAGB, LSG) have been favoured over mixed or malabsorptive procedures (e.g. *Roux-en-Y* gastric bypass, biliopancreatic diversion) (120). This preference appears to be explained by the lower post-surgery complication rates and risk of long-term nutritional deficiencies following restrictive bariatric procedures (3, 55). Successful weight loss has been reported at 12 months following restrictive bariatric surgery, with percentage of excess weight loss (%EWL) values ranging from 63% to 87% following LSG (121-124) and 30% to 46% following LAGB (125-130). Although little is known about how LSG compares with LAGB in different post-surgery outcomes, there are data to show greater weight loss following LSG (131-135). The most recent study comparing two large cohorts reported that, at 12 months post-surgery, those people who underwent LSG had a 26% greater %EWL than those who underwent LAGB (60% versus 34%; $p < 0.001$) (135). The mechanisms that explain the greater weight loss found following LSG than LAGB might be explained by a greater reduction in stomach capacity and in hormones involved in hunger regulation (134, 136, 137). Together with weight loss, a primary aim of bariatric surgery is the improvement and/or resolution of obesity-related comorbid conditions (3). It is well established that significant improvement and/or resolution of DM2, dyslipidaemia, hypertension, and obstructive sleep apnoea occurs at 12 months, and is sustained up to 5 years following restrictive bariatric surgery (121, 122, 124, 129, 130, 138-149).

Since impaired HRQoL has been reported as an important factor related to people's motivation to seek bariatric surgery, the effect of restrictive bariatric surgery on HRQoL has been extensively investigated, mostly measured using generic HRQoL questionnaires, and also with obesity-related quality of life questionnaires (150-153). Significant improvements in measures of generic and obesity-related quality of life, particularly those related to physical health, have been consistently reported at 12 months and up to 5 years following restrictive bariatric surgery (66, 129, 134, 141, 154-175).

In addition, obesity has been consistently associated with increased symptoms of depression and anxiety (176-178), and there is some evidence to show an association between obesity and increased symptoms of stress (179, 180). It is likely that the association between obesity and poorer mental health is bi-directional. Obesity could lead to psychological distress (e.g. increased symptoms of depression, anxiety and stress) through the development of obesity-related comorbid conditions, weight-related stigma and discrimination, and biological factors (e.g. dysregulation of the hypothalamic-pituitary-adrenocortical system) (176, 178). Alternatively, psychological distress could lead to obesity by stress-induced changes in eating (e.g. binge eating) and PA patterns (e.g. decreased participation in PA due to depression) (176, 178). Significant improvements in symptoms of depression and anxiety, measured using validated self-reported questionnaires, have been reported at 12 months and sustained up to 5 years following restrictive bariatric surgery (154, 156, 162, 167, 168, 181-191). The only study that investigated the effect of restrictive bariatric surgery on self-reported stress has indicated significant improvements at 12 months post-surgery; however, it failed to report the magnitude of change (186).

This programme of research has investigated changes in measures of weight, obesity-related comorbid conditions, HRQoL, obesity-related quality of life and weight-related symptoms, and symptoms of depression and anxiety in order to confirm that the investigation of PA and SB occurred in the context of responses to restrictive bariatric surgery that were as expected. But also, this programme of research provides novel data on the pattern of change in these outcomes, and additionally on the change in stress, over the first 12 months post-surgery. Although the effects of bariatric surgery on these outcomes are well-established, the pattern of change over the first 12 months post-surgery is unknown. This information is relevant to inform both patients and clinicians on the expected time course of change for these outcomes following surgery (153).

1.2 Study 2

The second study in this programme of research explored participants' perceptions of factors related to their participation in PA pre-surgery and 12 months following restrictive bariatric surgery.

1.2.1 Research questions

(i) Prior to restrictive bariatric surgery, what are participants' beliefs about PA, and perceived barriers and facilitators to PA?

(ii) Twelve months following restrictive bariatric surgery: (a) What are the perceptions of participants regarding their ability to participate in PA as well as barriers and facilitators to PA? (b) How do these perceptions differ from participants' perceptions pre-surgery? and (c) What are the perceived motivators to PA at 12 months following restrictive bariatric surgery?

1.2.1.1 Background

Promoting change in PA has been a challenge, with little or no change in PA levels found as a result of population-based initiatives which informed people about PA guidelines and suggested strategies to increase their participation in PA (192). Systematic reviews of randomised controlled trials (RCTs) investigating the effectiveness of interventions aimed at promoting PA among adults in the general population have reported at best, a modest effect on PA levels (i.e. effect sizes around 0.50) (193, 194). The modest effects found for interventions promoting PA in adults may be explained by the generic nature of these interventions, such as the use of generic advice and counselling regarding participation in PA. Although fewer RCTs have investigated the effectiveness of interventions aimed at increasing PA among people who are obese or those scheduled to undergo bariatric surgery, their findings suggest that those interventions that used a tailored approach addressing factors relevant to people's participation in PA appear to be more effective than interventions which used generic approaches to increase PA (34, 195, 196). For example, an RCT of candidates for bariatric surgery that compared a control group (i.e. standard pre-surgery care) to a comprehensive theory-based behavioural intervention, which consisted of individual counselling sessions addressing problem-solving for barriers to PA, goal setting regarding purposeful walking and used behavioural and cognitive strategies aimed at increasing self-efficacy and motivation to PA, reported a significant increase of 21.0 min/day (SD, 26.9) in total time spent in MVPA in the intervention group, while no change was seen in the control group (34). In contrast, an RCT of obese adults with DM2 that compared a control group (i.e., general education) to a more generic intervention, which consisted of individual educational sessions about benefits of PA and prescription of a PA program, reported a significant but modest increase of 5.5 min/day (SD, 2.9) in total time spent in MVPA in the intervention group, while no change was seen in the control group (195). Although these data indicate that a more tailored intervention can produce substantial and significant short-term increases in participation in PA pre-surgery, when targeting ways to counteract people's barriers to PA (i.e. factors that would make it difficult or prevent people from engaging in PA), and providing strategies to optimise facilitators to PA (i.e. factors that would make it easier for people to engage in PA), further research about barriers and facilitators to PA among people who undergo bariatric surgery is needed. Of note, in the study by Bond et al (34), only one in four people screened were randomised to participate in the study, which may have decreased the representativeness of the sample to those motivated to increase their PA. Further, since the intervention was performed pre-surgery, the long-term and post-surgery sustainability of any increase in PA following the completion of a behavioural intervention has not yet been investigated.

In the general population, there is a reasonable amount of information pertaining to barriers and facilitators to PA. Specifically, the most frequently reported barriers to PA in the general adult population include lack of time, lack of motivation, work and family commitments, lack of support or lack of company to engage in PA, and presence of pain or poor health (197-207). The most frequently reported facilitators to PA in the general population include being physically active with family members, being a role model for children, prioritising PA, and receiving social support (208-210). There is some evidence to show that population sub-groups may present particular factors that influence their participation in PA (211-213). Specifically, in addition to those barriers commonly found in the general population, people who are obese have consistently reported the presence of obesity-related barriers to PA, such as feeling overweight or obese, self-consciousness regarding their body image, and perceived lack of self-discipline or laziness (214-218). Barriers to PA may differ between people in different classes of obesity, due to differences in the prevalence of obesity-related comorbid conditions and the influence of the excess weight on participation in PA (214, 215, 217). People who are obese frequently reported weight loss as the most important facilitator to PA (219, 220).

Although there are some data on the barriers and facilitators to PA in the general population and people who are obese, these data may not be applicable to people who undergo bariatric surgery. This is because surgical treatment for obesity is usually considered after repeated unsuccessful attempts to lose weight using non-surgical treatment options, and people who are scheduled to undergo bariatric surgery may have a different perception of factors that influence their participation in PA, when compared to the general obese population (221). Thus, there remains a need for research on barriers and facilitators to PA specific to this population.

Study 2 uses a qualitative design to explore factors relevant to participation in PA, such as barriers, facilitators and motivators to PA, in people prior to and following restrictive bariatric surgery. In contrast, the majority of studies investigating barriers and facilitators to PA have used surveys and structured questionnaires or scales (206, 214, 215, 217, 222). Qualitative methods, such as interviews or focus groups, do not limit people's responses to pre-specified items and provide a rich, detailed exploration of why people participate or not in PA. Further, qualitative data provide an in-depth insight into people's experiences and perceptions of factors related to participation in PA within the social context of a particular population (202, 210, 223-225). Rich, in-depth and detailed information regarding pre- to post-surgery changes in factors related to participation in PA might give insight into the reasons why people participate in little PA pre-surgery and do not seem to increase their participation in PA following restrictive bariatric surgery. This information is relevant to inform clinicians and shape interventions that have the best chance of success at increasing participation in PA pre- and post-surgery and optimising post-surgery outcomes (74, 75, 226, 227).

1.3 Significance and novelty of the programme of research

Restrictive bariatric procedures have been increasingly used to manage obesity in Western countries (1). There is strong evidence that restrictive bariatric procedures result in substantial and sustained weight loss, as well as improvements in obesity-related comorbid conditions, HRQoL and symptoms of mental health disorders (3, 152, 167). There are data to suggest that, when compared to the general population, people scheduled to undergo bariatric surgery have lower participation in PA and spend more time in SB (21, 41). Further, despite the effectiveness of restrictive bariatric surgery for the treatment of obesity, the few studies that investigated pre- to post-surgery changes in objective measures of PA and SB suggest little or no change in these measures (4-8). However, these studies presented important limitations regarding the methods used to assess PA and SB, including low adherence to the motion sensor used (4) and suboptimal placement of the motion sensor around the waist or hip, which might decrease accuracy due to motion sensor tilt as a result of abdominal adipose tissue (5, 8). Further these studies focused on measures of MVPA and daily step count, and little attention has been given to the way in which people spend most of their waking hours, that is, time spent in SB and light intensity PA. In this respect, this programme of research was the first to collect objective measures of PA, at any intensity, and SB using two state-of-the-art devices, pre-surgery and every 3 months for the first 12 months post-surgery. Also, this programme of research was the first to investigate the pattern of change, over the first 12 months post-surgery, in measures of PA, SB, and other health outcomes relevant to participation in PA. This adds to the literature by providing robust data on the magnitude and pattern of change in objective measures of PA and SB following restrictive bariatric surgery. Information regarding the effect of surgery on time spent in PA and SB, as well as on the way PA and SB are accumulated is relevant to inform clinicians about whether or not additional interventions are needed to optimise post-surgery participation in PA, at any intensity, and provides data to guide behavioural interventions in this population. This is important because the detrimental effects of participation in little PA and increased time in SB are independent of obesity (43-45, 57-65). Thus, despite large weight loss post-surgery, if people do not change their PA and SB, they remain at risk of the detrimental health effects of this lifestyle. Additionally, participation in the recommended amounts of MVPA and decreased time spent in SB has been associated with better post-surgery outcomes (66-69). The data on the pattern of change in PA, SB, and other health outcomes post-surgery could be useful for clinical practice, in order to inform patients' expectations of realistic post-surgery results and guide content and timing for interventions aimed at optimising participation in PA in this population.

This programme of research has also investigated outcome measures that are novel and relevant to PA. Information about the effect of surgery on outcomes that may influence, or be influenced by, participation in PA, such as cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, body composition and BMD, could provide clinicians with additional factors to consider with regards to optimising participation in PA among people who undergo restrictive bariatric surgery. The investigation of change in weight, obesity-related comorbid conditions, HRQoL, obesity-related quality of life and weight-related symptoms, and symptoms of mental health disorders was performed to ensure that the estimation of PA changes was made in the context of the expected responses to restrictive bariatric surgery with regard to these outcomes.

It is likely that people who undergo restrictive bariatric surgery will need additional interventions to improve their participation in PA, as post-surgery weight loss alone may not result in changes in PA. This programme of research is the first to provide a longitudinal in-depth exploration of people's perceptions of factors related to their participation in PA pre- and post-surgery and how these perceptions changed following restrictive bariatric surgery. This in-depth information contributes to the understanding of why there may be a lack of favourable changes in people's PA and SB following restrictive bariatric surgery and may help to shape behavioural interventions aimed at optimising participation in PA in this population.

CHAPTER 2 LITERATURE REVIEW

Overview

This chapter reviews the literature pertaining to the development of the research questions and methods used in the studies that comprise this programme of research. Section 2.1 defines obesity and presents information concerning its prevalence, health implications and healthcare burden. Section 2.2 outlines the available management approaches to obesity. Section 2.3 discusses the influence of restrictive bariatric surgery on health outcomes. Section 2.4 provides an overview on physical activity (PA) and sedentary behaviour (SB) and comprises definitions, recommendations, assessment methods, and health implications. Section 2.5 discusses PA and SB measures prior to and following bariatric surgery. Section 2.6 outlines the available evidence on perceived barriers and facilitators to PA prior to and following bariatric surgery.

2.1 Obesity

This section provides information on the definition and prevalence of obesity, as well as its health implications and associated healthcare burden. Particular attention is given to the health implications of obesity, with an outline of the evidence pertaining to the association between obesity and several comorbid conditions.

2.1.1 Definition and prevalence

Obesity is defined as an abnormal or excessive accumulation of fat that may impair health (18). It is most commonly caused by an imbalance between energy consumption (i.e. dietary intake) and energy expenditure (i.e. energy loss due to metabolic and physical activities) (228). The prevalence of obesity among adults has increased rapidly. In 2014, the World Health Organisation estimated that more than 1.9 billion adults worldwide were overweight, and of these, over 600 million were obese (18). The most recent data from the Australian Health Survey showed that in 2011-2012, 63% of Australian adults were overweight or obese, which represented a 7% increase from 1995 (19).

There are several factors that influence the development of obesity, including genetic, metabolic, behavioural, and environmental factors (228, 229). The speed with which the prevalence of obesity has increased suggests that behavioural and environmental factors, such as changes in eating habits (e.g. high availability of processed foods), and a decrease in PA levels (e.g. increased use of motor vehicle transportation and shift from active to sedentary occupations) have been greater contributing factors to the obesity epidemic, compared to genetic and metabolic factors (e.g. genetic abnormalities or endocrine disruptors resulting in weight gain) (228, 229). The most widely used measurement of body fat is the body mass index (BMI; weight in kilograms divided by height in metres squared). Thresholds have been established using BMI to classify adults as normal-weight (18.5 to 24.9 kg/m^2), overweight (≥ 25 kg/m^2), and obese (≥ 30 kg/m^2). The category of obese has been further classified into classes I (30 to 34.9 kg/m^2), II (35 to 39.9 kg/m^2), and III (> 40 kg/m^2) (230). Most recently, measurement of waist circumference, an important predictor of abdominal obesity, has also been used as a measure of obesity and has been suggested as a better predictor of cardiovascular disease (CVD) and diabetes mellitus type 2 (DM2) than the traditional BMI (231). The measurement of waist circumference may be a better predictor of CVD and DM2 since abdominal obesity is a known risk factor of CVD and DM2 (232). According to the World Health Organisation, the risk of metabolic complications associated with abdominal obesity is substantially increased with waist circumference > 88 cm for women, and > 102 cm for men (230).

2.1.2 Health implications

Obesity has been associated with the risk of developing various comorbid conditions, such as DM2, CVD and associated risk factors, musculoskeletal disorders (e.g. osteoarthritis), increased symptoms of mental health disorders (e.g. depression and anxiety), sleep problems (e.g. obstructive sleep apnoea), some types of cancer, and increased risk of both all-cause and cause-specific mortality. The following paragraphs summarise the evidence pertaining to the association between obesity and different comorbid conditions, and provide an overview of the possible mechanisms by which obesity is associated to the development and maintenance of such conditions.

The association between obesity and DM2, a common chronic disease that affects glucose metabolism, has been established in several large observational studies (233-236) and subsequent meta-analyses (231, 237). Specifically, a strong dose-response association between DM2 and various measures of obesity (e.g. BMI, waist circumference, waist-hip ratio) has been consistently demonstrated. The most recent meta-analysis indicates that obese men and women (i.e. BMI > 30 kg/m^2) have a statistically significant higher risk for DM2 compared to those in the normal-weight range, with relative risks ranging from 6.7 to 12.4 (231). Similar associations were observed when obesity was assessed by other measures, such as waist circumference. The suggested mechanisms that may explain the development and persistence of DM2 in people who are obese include a reduction in insulin receptors and insulin resistance, both of which accompany excess fat accumulation and ultimately alter glucose metabolism (238).

Obesity has also been associated with several risk factors (e.g. dyslipidaemia, hypertension) that contribute to the development of different types of CVD, such as coronary heart disease, congestive heart failure, and stroke. Associations between obesity and dyslipidaemia (i.e. elevated triglycerides and cholesterol levels) have been consistently demonstrated (239-242). Longitudinal investigations have reported that, when compared to people in the normal-weight range, obese men and women presented with 60 to 100 mg/dL higher triglycerides levels (241), and with 17 to 23 mg/dL higher total and low-density lipoprotein cholesterol levels (239, 240). A meta-analysis of cohort studies has also reported statistically significant associations between another CVD risk factor, hypertension, and obesity in adults, with relative risks ranging from 1.8 to 2.4, when compared with people within the normal-weight range (231). Similar findings have been demonstrated for risk of coronary heart disease, congestive heart failure, and stroke (231, 243, 244). Complex mechanisms have been proposed to explain the association between obesity and CVD, including obesity-related metabolic issues (e.g. hypertension, elevated triglycerides and cholesterol, impaired glucose tolerance), as well as increased systemic inflammation and oxidative stress that lead to endothelial dysfunction and atherosclerosis (245, 246). The effects of increased cardiac output, and of epicardial and myocardial fat accumulation on cardiovascular function have also been related to increased risk of cardiac failure (245, 246).

Obesity has been implicated in the development and persistence of diverse musculoskeletal conditions, such as osteoarthritis of the lower limbs and hands, soft tissue conditions (e.g. plantar fasciitis) (247-250), and low back pain (251). Obesity is known to be a risk factor for both incidence and progression of osteoarthritis (248, 252). For instance, a large cohort study (n = 1,854) with a 10-year follow-up period has reported associations between obesity and incident osteoarthritis with odds ratios of 2.8 (95% confidence interval [CI], 1.3 to 5.9) for osteoarthritis of the knee and 2.6 (95% CI, 1.1 to 6.2) for osteoarthritis of the hand (248). The suggested mechanisms by which obesity affects the musculoskeletal system are related to the functional and structural limitations imposed by the excessive weight on musculoskeletal structures, as well as metabolic factors, such as an increase in systemic inflammatory mediators (250, 253).

Disturbances in mental health, reported as increased symptoms of depression and anxiety, have been associated with obesity (176-178, 254). The most recent large observational study (n = 6,514), with a 12-year follow-up period, reported moderate significant associations (i.e. hazard ratio of 1.1) between the onset of clinically relevant symptoms of depression and obesity, when compared to people in the normal-weight range (254). Results from the World Mental Health Surveys initiative, a compilation of general population surveys from 13 countries in North and South America, Europe, Middle East and Asia/Pacific regions, demonstrated moderate significant associations, with odds ratios ranging from 1.1 to 1.5, between obesity and depressive and anxiety disorders, assessed by a structured diagnostic interview (177). Although studies that investigated the association of obesity and perceived stress are scarce, data suggest that stress is positively associated with higher body weight (180, 255, 256). Observational studies have also reported moderate significant associations, with odds ratios ranging from 1.1 to 3.4, between obesity, assessed by BMI and waist circumference, and perceived general or work-related stress among men and women (179, 256). Although different factors have been suggested to explain the association of obesity and poorer mental health, the underlying mechanisms remain uncertain. The suggested mechanisms by which obesity is associated with poorer mental health include psychological stress caused by health issues related to obesity, negative effects of weight-related stigma and discrimination, biological factors (e.g. dysregulation of the hypothalamic-pituitary-adrenocortical system), and stress-induced changes in eating and PA patterns (176, 178).

Sleep problems are prevalent among people who are obese and can include sleep disordered breathing, particularly obstructive sleep apnoea (OSA), as well as poor sleep quality and excessive daytime sleepiness. Obesity has been shown to be a strong correlate of OSA, and the prevalence of OSA among people who are obese is around 40% to 50% (87). A large cohort study (n = 690) has demonstrated that over a 4-year period, a 10% to 20% increase in body weight, when compared to no weight gain, was significantly associated with a 32% to 70% increase in the apnoea-hypopnoea index (AHI), an index of OSA severity measured using and overnight sleep study (257). Poor sleep quality and excessive daytime sleepiness are common complaints among people who are obese, when compared to those in the normal-weight range, even in the absence of sleep-disordered breathing (88, 258). Anatomical factors (e.g. fat deposits in the upper airway, changes in airway shape, increased neck circumference), neuromuscular factors (e.g. decreased upper airway musculature tone), and hormonal factors (e.g. alterations in the hormone leptin that can affect respiratory control) have all been suggested as contributors to the development of sleep problems, particularly OSA, among people who are obese (259, 260). The presence of poor sleep quality and excessive daytime sleepiness in the absence of OSA suggests that obesity itself is related to such disorders; however, the mechanisms of these association are still unknown (88, 258).

Considering the range of factors involved in the development and persistence of obesity-related comorbid conditions, the mechanisms that explain the associations between obesity and its related comorbid conditions appear to be influenced by complex interactions between biological (e.g. metabolic and hormonal dysregulation, increased systemic inflammation and oxidative stress), mechanical (e.g. functional and structural limitations caused by excess weight) and psychosocial factors (e.g. weight-related stigma, increased symptoms of depression and anxiety). Additional issues, such as low levels of PA, may compound the complex interactions between various biological, mechanical and psychosocial factors and the increased risk of comorbid conditions, resulting in further impairments. For instance, one such interaction may involve mechanical and psychosocial factors (e.g. presence of osteoarthritis or gait limitations and lethargy related to depressive symptoms) that may have a role in the cardiovascular fitness impairment found among people who are obese (76-79). The resulting impairment in cardiovascular fitness, in turn, may be associated with decreased ability to engage in PA among people who are obese. Decreased cardiovascular fitness and little participation in PA are likely to play a role in the persistence of CVD risk factors observed in obese populations (261-263).

The combination of mechanisms by which obesity influences the development and persistence of comorbid conditions and the complex interplay between these conditions and confounding factors (e.g. participation in PA) are likely to contribute to people’s impaired health-related quality of life (HRQoL) (264, 265). Additionally, when compared to their normal-weight counterparts, the obesity-related comorbid conditions and impairments of cardiovascular fitness and HRQoL result in increased risk of both all-cause and cause-specific mortality among people who are obese (266-268).

2.1.3 Healthcare burden

When combined, obesity-related comorbid conditions impose considerable burden on the healthcare system. A systematic review that included 32 studies, published from 1990 to 2009, investigated the costs associated with obesity in both Western and Eastern countries (269). The results showed that the medical costs of people who were obese were around 30% greater when compared to those within the normal-weight range. The direct costs associated with obesity were estimated to be between 1% and 3% of a country's overall healthcare expenses (269). According to data from the Australian Diabetes, Obesity and Lifestyle study, a national population-based study conducted in 1999-2000 with a follow-up survey in 2004-2005, the total direct health cost (i.e. ambulatory services, hospitalisation, prescription medication, and some medically-related consumables) for being overweight or obese to Australia was AUD$21 billion per year, of which AUD$14.5 billion was associated with obesity alone (270). Colagiuri et al (270) also compared direct health costs by weight change from 1999-2000 to 2004-2005. The annual direct health costs were highest for people who were obese (AUD$2,853 per person) in both surveys, and decreased by about 30% for those people who were overweight or obese and lost weight between the first and second surveys (AUD$1,982 per person) (270).

2.2 Management approaches to obesity

The main objective of obesity treatment is to achieve a substantial reduction of body weight and to maintain the weight loss in the long term. Weight loss, even as little as 5% to 10% of initial body weight, is known to have beneficial effects on CVD risk factors, such as hypertension, dyslipidaemia, and DM2 (271-273). Successful weight loss maintenance has been defined as intentional loss of at least 10% of initial body weight that is maintained for at least 1 year (274). Different approaches have been used for the management of overweight and obesity, and for the purpose of this literature review, the management approaches will be divided into and described according to non-surgical and surgical treatments. Literature pertaining to the effect of non-surgical treatment on weight loss and obesity-related comorbid conditions (i.e. DM2 and CVD) will also be discussed. However, as the focus of this programme of research was on surgical treatment for obesity, the evidence on the influence of bariatric surgery on different health outcomes, as well as PA and SB pre- and post- bariatric surgery will be discussed in more detail in sections 2.3 (Influence of restrictive bariatric surgery on health outcomes) and 2.5 (Physical activity and sedentary behaviour prior to and following bariatric surgery), respectively.

2.2.1 Non-surgical treatment for obesity

Different non-surgical approaches have been used for the treatment of obesity, all of which aim to create a negative energy balance (i.e. when calorie intake is lower than calorie expenditure). These approaches include dietary interventions, exercise interventions, lifestyle interventions (i.e. combination of dietary and exercise interventions, with or without behavioural therapy), as well as pharmacotherapy (275-278). Caloric restriction is the key feature of diet-induced weight loss, with recommended energy intakes between <800 and 1,000-1,500 kilocalories per day for very low calorie and low calorie diets, respectively (279, 280). Several randomised controlled trials (RCTs) and systematic reviews of RCTs have sought to determine the effectiveness of any one diet over another, as well as over no treatment (281-285). These RCTs have demonstrated significant but modest weight lost for diets of at least 12 months of duration, with scarce data on the effectiveness of different diets on improvement and/or resolution of obesity-related comorbid conditions. The largest systematic review of RCTs comparing diet alone to no treatment reported modest results, with a mean difference in weight loss over a 12-month follow-up period, when compared to no treatment, of -5.3 kg (95% CI, -5.8 to -4.7) with low fat diet, -6.2 kg (95% CI, -9.0 to -3.4) with low calorie diet, and -13.4 kg (95% CI, -18.3 to -8.3) with very low calorie diet (281). Although diets with different daily energy intake and different proportions of macronutrients (i.e. fat, protein, carbohydrate) have been used, there is minimal evidence to support one over another (283, 284). Atallah et al (283) performed a systematic review of 12 RCTs that investigated the effects of four popular diets on weight loss, with follow-ups ≥ 12 months, including Atkins (i.e. very low carbohydrate with unlimited protein and fat), South Beach (i.e. low carbohydrate and high protein), Weight Watchers (i.e. caloric restriction in addition to a behaviour modification plan), and Zone (i.e. low carbohydrates and recommendation for intake of low fat proteins, low glycaemic load carbohydrates, and small amounts of good fat). At 12 months, findings from studies that compared more than one diet to usual care suggested modest and similar weight loss between all groups, ranging from 1.6 to 4.7 kg. Their results also reported no long-term improvements in CVD risk factors, such as lipid levels, blood pressure and glycaemic control. An RCT that compared the effects of low carbohydrate (n = 60) to low fat (n = 59) diets, of 12 months duration, on weight and CVD risk factors found that both resulted in small but significant weight loss, 3.5 kg greater for the low carbohydrate diet group (5.3 kg; 95% CI, 3.8 to 6.8) than the low fat diet group (1.8 kg; 95% CI, 0.3 to 3.3) (284). Also at 12 months, the low carbohydrate diet group had significant reductions in the ratio of total and high-density lipoprotein cholesterol and triglycerides, as well as increase in high-density lipoprotein cholesterol, while no significant change was found in the low fat diet group.

Energy balance is also affected by energy expenditure as a result of PA (i.e. any bodily movement that results in energy expenditure) and/or exercise, which is defined as planned, structured, and repetitive PA which is intentionally undertaken with the goal of improving health and fitness (42). A high degree of heterogeneity has been found in studies that have investigated the effect of PA or exercise interventions, regarding the modality of PA or exercise used (e.g. aerobic versus resistance exercise), intensity and frequency of activities, duration of intervention, and supervised or unsupervised nature of the intervention (286, 287). Several studies have demonstrated that exercise interventions, when compared to no intervention, are ineffective in producing meaningful changes in body weight (278). Specifically, systematic reviews and meta-analyses of studies investigating the effects of exercise-only interventions reported small average weight loss ranging from 1.3 to 3.0 kg (286-288). Despite the modest magnitude of weight loss, there is evidence to support that engagement in PA and/or exercise produces a reduction in CVD risk factors (e.g. blood glucose, blood lipids, blood pressure) (287, 289-293). For example, a Cochrane systematic review reported that exercise as a sole intervention resulted in significant reductions in CVD risk factors, such as diastolic blood pressure (-2 mmHg; 95% CI, -4 to -1), triglycerides (-0.2 mmol/L; 95% CI, -0.3 to -0.1), and fasting glucose (-0.2 mmol/L; 95% CI, -0.3 to -0.1) (287).

The modest weight loss achieved with diet or exercise alone has led to the investigation of lifestyle interventions, which combine diet and exercise, with or without behavioural therapy (294-298). A recent systematic review and meta-analysis included RCTs that compared behavioural weight management interventions combined with diet and exercise (i.e. lifestyle intervention), with diet-only or exercise-only, with a minimum follow-up period of 12 months (298). Results from the six RCTs that compared lifestyle versus diet-only interventions showed similar weight loss achieved at 3 to 6 months, but greater weight loss in the lifestyle intervention groups at 12 months (mean difference, -1.7 kg; 95% CI, -2.8 to -0.6). When comparing lifestyle versus exercise-only interventions, the lifestyle intervention groups had greater weight loss both at 3 to 6 months (mean difference, -5.3 kg; 95% CI, -7.6 to -3.0) and 12 to 18 months (mean difference, -6.3 kg; 95% CI, -7.3 to -5.2) (298). Regarding the effect on obesity-related comorbid conditions, an earlier systematic review and meta-analysis of RCTs that investigated the effect of lifestyle interventions in people who were overweight and obese, that ranged between 1 and 6 years in duration, reported a significant reduction in CVD risk factors in the mid to long-term (i.e. an average follow-up period of 3 years) (299). That is, when compared to control groups (described as receiving standard care), lifestyle interventions resulted in reduced systolic blood pressure (-3 mmHg; 95% CI, -4 to -1), diastolic blood pressure (-1 mmHg; 95% CI, -2 to -1), total cholesterol (-0.1 mmol/L; 95% CI, -0.2 to -0.03), triglycerides (-0.1 mmol/L; 95% CI, -0.3 to -0.04), and 2-hour plasma glucose (-0.5 mmol/L; 95% CI, -0.8 to -0.2).

A large amount of medications have been used as an adjunct to non-surgical interventions to promote weight loss, and several have been removed from the market due to safety issues (300). In Australia, Orlistat, a gastrointestinal fat blocker, is the only medication registered and approved for long-term use, while Phentermine, an appetite suppressant, is registered for short-term use only (277). Systematic reviews of placebo-controlled RCTs and individual RCTs have reported significantly greater weight loss in the medication groups (i.e. Orlistat or Phentermine), ranging from 2.9 to 3.6 kg, when compared to placebo groups (301-303). Most trials also showed significant improvements in CVD risk factors, such as cholesterol, blood pressure, and glycaemic control (301-303). Of note, several adverse effects have been reported with Orlistat and Phentermine use, and the long-term effects of these drugs on weight loss and management of obesity-related comorbid conditions are unknown (300, 301 , 303).

Several studies have reported modest (i.e. < 10% of initial weight) but significant weight loss and improvements in CVD risk factors following different non-surgical treatments (281, 287, 298). The combination of different strategies aimed at weight loss (i.e. diets, exercise, behavioural interventions, pharmacological) has been shown to result in greater weight loss than any one strategy alone (298, 304).

Although non-surgical treatments may produce short-term weight loss, studies that have investigated long-term weight loss maintenance (i.e.1 to 4 years) following non-surgical interventions have reported that only a small amount of weight loss, mostly lower than 5% of initial weight, is maintained in the long-term (304-306). Further, the long-term effectiveness of these treatments on improvement and/or resolution of obesity-related comorbid conditions is yet unknown (304, 307).

2.2.2 Surgical treatment for obesity

Surgical treatment for obesity, known as bariatric surgery, has been increasingly performed, particularly in Western countries, to counteract obesity and obesity-related comorbid conditions (1, 120). This is because, in contrast to non-surgical approaches, bariatric surgery has been shown to confer substantial (i.e. ≥ 10% of initial weight) and sustained weight loss, accompanied by significant improvement and/or resolution of obesity-related comorbid conditions (2, 3). According to the latest report from the Australian Institute of Health and Welfare, the number of bariatric surgeries performed in Australia has increased from approximately 500 procedures performed in 1998-1999 to 17,000 in 2007-2008 (308). The most recent worldwide survey of bariatric surgery has shown that, from 2003 to 2013, 10,467 bariatric procedures were performed in Australia and New Zealand and of these, 3,163 (30%) were adjustable gastric banding, 6,660 (64%) were sleeve gastrectomy, and the remaining 644 (6%) were *Roux-en-Y* gastric bypass (RYGB) (120). Surgical approaches are classified according to the anatomical change they produce as either restrictive, malabsorptive, or mixed procedures (3, 309). The restrictive procedures aim to reduce stomach capacity in order to accelerate satiety with reduced food intake, and include laparoscopic adjustable gastric banding (LAGB) and laparoscopic sleeve gastrectomy (LSG) (309). Laparoscopic adjustable gastric banding is a minimally invasive procedure in which an adjustable silicone band is placed around the entrance of the stomach, resulting in limitation of food intake through reducing the volume of the stomach (309). Adjustments are performed non-surgically, by the addition or removal of saline through a subcutaneous port to create a gastric pouch of 15 to 30 mL (309). Laparoscopic sleeve gastrectomy removes a major portion of the stomach along a vertical line, forming a small tubular shape to the stomach with a volume of 60 to 80 mL (about 25% of its original size) (309). Sleeve gastrectomy was introduced as a first step of a two-step procedure in people with class III obesity, which was followed by a conversion to either gastric bypass or a duodenal switch at a later date. However, due to the successful weight loss achieved, it has been increasingly performed as a stand-alone procedure (3). The malabsorptive procedures, such as biliopancreatic diversion with or without duodenal switch, bypass the foregut preventing the complete absorption of food eaten (309). Mixed procedures combine restrictive and malabsorptive techniques, such as RYGB (309). Restrictive procedures have been preferred over the malabsorptive or mixed procedures, due to lower risk of both surgical complications, and nutritional deficiencies (3, 55).

2.2.3 Summary

Obesity is a highly prevalent condition that has been consistently associated with increased risk for the development and maintenance of important health conditions (e.g. DM2, CVD, cancer, impaired HRQoL and mental health) (266, 310). Obesity has also been associated with increased all-cause and cause-specific mortality (266, 310). The management of obesity is complex, and despite successful weight loss and improvement in some obesity-related comorbid conditions achieved with non-surgical treatment options, the majority of people regain most of the weight over the first few years following the intervention (304, 311, 312). In addition, the long-term effects of non-surgical treatment options on obesity-related comorbid conditions are yet unclear (306). In Australia, bariatric surgery, particularly restrictive procedures, has been increasingly used for the management of obesity (1, 120, 308).

2.3 Influence of restrictive bariatric surgery on health outcomes

As the programme of research described in this thesis focuses on restrictive bariatric procedures, this section reviews the evidence for the effects of LAGB and LSG, rather than the malabsorptive or mixed procedures, on outcomes such as measures related to weight (e.g. weight, BMI, waist circumference), obesity-related comorbid conditions (i.e. DM2, CVD and associated risk factors), body composition and bone mineral density (BMD), cardiovascular fitness, sleep problems (i.e. OSA, sleep quality and daytime sleepiness), HRQoL, and symptoms mental health disorders. The most commonly used measurement methods or instruments to measure changes in the aforementioned outcomes are also discussed. These outcomes are related to those investigated in the first study undertaken in this programme of research. For this section, the studies first described are those in which the changes in a group that underwent surgery were compared with changes in a control group that participated in a non-surgical weight loss treatment. Thereafter, studies are described in which the effect of surgery was reported in a single group without any comparison with a control group (i.e. case series). Given the main focus of the two studies that comprised this programme of research was to examine the influence of restrictive bariatric surgery on PA and SB, data on changes in PA and SB following restrictive bariatric surgery will be reviewed in section 2.5 (Physical activity and sedentary behaviour prior to and following bariatric surgery).

2.3.1 Weight-related measures

Several studies have investigated weight loss following bariatric surgery alone or in comparison to non-surgical weight loss treatment. However, these studies are heterogeneous in regards to type of surgical procedure, type and duration of non-surgical treatment, participant selection procedures, sample characteristics and outcome measures used (3, 313). Different measures of weight change have been reported including absolute weight (expressed in kg), BMI, and percentage of excess weight loss (%EWL), with excess weight defined as the difference between people's weight and their ideal weight (i.e. weight for a BMI of 25 kg/m^2) (3). The measurement of waist circumference has also been used to investigate abdominal obesity (2). The use of different weight parameters as outcome measures for weight change post-surgery often creates difficulties when comparing studies' findings (3, 314).

Several RCTs and non-randomised controlled trials that compared the effects of restrictive bariatric surgery to non-surgical weight loss treatments have reported greater weight loss among people who underwent LAGB (144, 161, 315-319) and LSG (320-322). The most recent RCT investigated 45 obese adults with diagnosed DM2, and found LAGB to be superior to a 12-month non-surgical intervention that included diet, exercise, and advice on medication for DM2 (319). At 12 months, the mean weight loss in the surgical group was 5 kg greater when compared to the non-surgical group (13.5 kg versus 8.5 kg; $p = 0.03$). Friedrich et al (321) performed the largest non-randomised controlled trial to compare the effects of LSG ($n = 27$) to a 12-month non-surgical weight loss treatment ($n = 27$) that included diet, exercise, and behavioural interventions. At 12 months, the mean weight loss in the surgical group, expressed as the %EWL was 27% greater when compared to the non-surgical group (65% versus 38%; $p < 0.001$). The same pattern of greater reduction in waist circumference has been reported following restrictive bariatric surgery, when compared to non-surgical treatment, and sustained reductions in waist circumference, ranging from 9.2 to 20.7 cm, have been reported up to 5 years post-surgery (130, 143, 316, 319, 322).

Several case series have reported significant and sustained weight loss, ranging from 38 to 60 %EWL, up to 15 years following LAGB (125-130, 142), and from 49 to 84 %EWL up to 6 years following LSG (121-124, 148, 162, 323). Although successful weight loss has been found following both types of restrictive bariatric surgery, studies that compared LAGB and LSG have consistently reported greater weight loss following LSG (131-135). The most recent study compared two matched cohorts and reported greater %EWL following LSG (n = 2,949), when compared to LAGB (n = 2,949), with a difference of 26% at 12 months (60% versus 34%; $p < 0.001$), 20% at 2 years (60% versus 40%; $p < 0.001$), and 12% at 3 years post-surgery (56% versus 44%; $p < 0.001$) (135).

Despite the heterogeneity in the sample characteristics, surgery technique, and measures of reporting weight change (e.g. absolute weight, %EWL, waist circumference), there is evidence to show a pattern of significant and sustained weight loss following restrictive bariatric surgery (2, 3, 313). Although the mechanisms that explain differences in weight loss following LAGB and LSG are not yet clear, factors such as a greater reduction in stomach capacity and hormones involved in hunger regulation may explain the greater weight loss found after LSG (134, 136, 137). Several studies that have demonstrated sustained weight loss following restrictive bariatric surgery found that most of the weight loss was achieved during the first 12 months following the procedure, and mostly maintained up to 15 years post-surgery (122-126, 128, 144, 324, 325). However, the pattern of change in weight-related measures over the first 12 months following restrictive bariatric surgery is yet unknown. This information is important to inform both patients and clinicians on the expected time course of change in weight following surgery.

2.3.2 Diabetes mellitus type 2, cardiovascular disease and associated risk factors

Together with weight loss, a primary aim of bariatric surgery is to produce significant improvement and/or resolution of obesity-related comorbid conditions, such as DM2, CVD, and associated risk factors (e.g. metabolic syndrome) (3). The improvement and/or resolution in these conditions has been ascertained by either self-report or the magnitude of change in objective measures (e.g. blood tests). However, the magnitude of change used to categorise improvement and/or resolution of a comorbid condition often differs between studies (3, 326).

Systematic reviews of RCTs that compared the effects of bariatric surgery and non-surgical weight loss treatments have reported greater improvement and/or resolution of obesity-related comorbid conditions for those people who underwent surgical treatment, regardless of the procedure used (2, 3). Regarding specific types of surgery, RCTs of LAGB and non-randomised controlled trials of LSG that have compared restrictive bariatric surgery to non-surgical weight loss treatments have mostly reported greater improvement and/or resolution of obesity-related comorbid conditions post-surgery (315-322). The most recent non-randomised controlled trial found a higher resolution of DM2 (36% versus 0%; $p = 0.007$) and hypertension (29% versus 0%; $p = 0.018$) for those who received LSG when compared to non-surgical treatment at 12 months post-surgery (322). In contrast, a recent RCT was the only study to report that those who received LAGB or a 12-month intensive non-surgical weight loss treatment had comparable benefits on diabetes control and cardiometabolic risk (319). The non-surgical intervention used in this study provided a greater emphasis on diet composition, duration and type of exercise, and adjustments in DM2 medication when compared to usual lifestyle interventions. The more intensive nature of the non-surgical weight loss treatment used might explain the comparable benefits observed for diabetes control and cardiometabolic risk despite the greater weight loss achieved by the LAGB group.

Several case series have reported significant and sustained improvement and/or resolution of obesity-related comorbid conditions up to 5 years following LAGB (129, 130, 138-144) and LSG (121, 122, 124, 145-149). The most recent case series of people undergoing LAGB found significant reductions in cardiometabolic risk factors and the prevalence of metabolic syndrome at 5 years after surgery (130). Compared with the percentage of participants who had metabolic syndrome pre-surgery, there was a significant reduction in the number with metabolic syndrome at 12 months (from 43% to 15%) and 5 years (from 43% to 13%). There was also a significant reduction in triglycerides levels of 69 mg/dL (from 155 mg/dL to 86 mg/dL) and a significant increase in high-density lipoprotein cholesterol levels of 10 mg/dL (from 57 mg/dL to 67 mg/dL) at 12 months, which were maintained up to 5 years (130). The case series with the longest follow-up period after LSG found that more than 70% of participants who had evidence of DM2, hypertension or dyslipidaemia pre-surgery demonstrated improvement and/or resolution of these conditions 5 years post-surgery (148).

The use of different measures (e.g. self-report versus objective measures) to assess and report changes in obesity-related comorbid conditions may limit the comparison of findings from different studies that investigated the effects of restrictive bariatric surgery on these outcomes (314). Despite the use of different outcome measures, studies show a consistent pattern of significant and sustained improvement and/or resolution of obesity-related comorbid conditions that accompanies the large and sustained weight loss following restrictive bariatric surgery (3, 132, 135, 146, 326).

2.3.3 Body composition and bone mineral density

Although weight loss has been extensively investigated following restrictive bariatric surgery, the effect of surgery on body composition and BMD has received less attention. Changes in body composition and BMD as a consequence of bariatric surgery are important considerations, as reductions in muscle and bone mass have been associated with poor health outcomes, including osteoporosis, increased risk of fractures, increased risk of falls, and functional impairment (i.e. limitations in mobility performance, such as walking and climbing stairs), particularly in older adults (114, 327, 328). Changes in muscle and bone mass can be measured by changes in body composition, particularly fat-free mass (FFM) or lean body mass (LBM), and BMD. The term LBM is often used interchangeably with FFM, and refers to the combination of FFM and small amounts of essential fat (329, 330).

Different methods can be used to assess body composition and BMD, including magnetic resonance imaging, computed tomography, whole-body dual energy x-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), and anthropometric measurements (e.g. BMI, waist and hip circumferences) (331). Studies of restrictive bariatric surgery have mostly used BIA to assess change in body composition, although some have used DXA (110, 113, 321, 332). Bioelectrical impedance analysis appears to be the most widely used method due to its low cost and ease of access and application. However, it is restricted to whole body composition measures and has limited accuracy, particularly in obese populations (331, 333). For instance, a study that compared measures of FM obtained via DXA and BIA reported that BIA produced values for FM which were, on average, 2% to 6% lower than those measured with DXA (334). Whole-body dual energy x-ray absorptiometry provides more accurate measurements of body composition than BIA, and also provides regional measures in addition to whole body measures (331). Additionally, DXA can be used to assess BMD, while exposing people to a low dose of radiation, with lower cost and more accessibility than more advanced technologies such as magnetic resonance imaging and computed tomography (331). However, the investigation of changes in BMD following bariatric surgery may be limited due to difficulties in obtaining valid and reliable BMD measures using DXA in people who are obese. These difficulties include logistic issues regarding limits in body weight and size of scan tables, as well as technical issues regarding to the unpredictable impact of soft tissue (e.g. fat tissue) artefact on BMD imaging when using DXA (335).

As restrictive bariatric surgery confers substantial weight loss, it is expected that FM loss will also be substantial following surgery. Two RCTs and a non-randomised controlled trial compared the effects of restrictive bariatric surgery and non-surgical weight loss treatments on FM measures (319, 321, 332). When compared to the loss of FM following non-surgical weight loss treatment, studies reported a greater loss of FM at 12 to 24 months following restrictive bariatric surgery, with between-group differences ranging from 1.3 to 21.5 kg (319, 321, 332). These measures were made using either DXA (332) or BIA (319, 321). Several case series of LAGB have consistently reported significant post-surgery reductions in FM, measured using either BIA or DXA, ranging from 10.4 to 32.7 kg, at follow-up periods between 6 months to 2.5 years (99, 100, 102, 103, 105, 106, 110, 113, 336-338). Similarly, several case series of LSG have consistently reported significant post-surgery reductions in FM, mostly measured using BIA, ranging from 21.0 to 38.9 kg, at follow-up periods between 6 to 12 months (104, 107-113).

Given the substantial weight loss that occurs following restrictive bariatric surgery, it seems reasonable to expect that this surgery may also result in loss of FFM or LBM. Two RCTs and a non-randomised controlled trial compared the effects of restrictive bariatric surgery and non-surgical weight loss treatments on FFM or LBM measures (319, 321, 332). Two of the three studies found a similar reduction in FFM or LBM following restrictive bariatric surgery when compared to non-surgical treatment at 12 months, measured using BIA (319, 321). The RCT by Dixon et al (332) was the only one to report a statistically significant 1.6 kg difference in FFM loss between the group who received LAGB (2.9 kg) and the non-surgical group (1.3 kg; $p = 0.002$). In contrast with the other two studies using BIA, the DXA measures of the latter study might have been more sensitive to assess changes in FFM. Several case series of

LAGB have reported significant post-surgery reductions in FFM or LBM, measured using either BIA or DXA, ranging from 2.1 to 9.0 kg, at follow-up periods between 1 to 2 years (100, 102, 103, 106, 110, 113, 337, 338). Similarly, several case series of LSG have reported significant post-surgery reductions in FFM or LBM, mostly measured using BIA, ranging from 6.1 to 15.4 kg, at follow-up periods between 6 to 12 months (104, 107, 108, 110-113).

The substantial weight loss that occurs following restrictive bariatric surgery may also involve reductions in BMD. Of note, no study to date has compared the effects of restrictive bariatric surgery to non-surgical weight loss treatments on measures of BMD. The majority of the case series found no significant changes in total body BMD, assessed using DXA, at follow-up periods between 6 months to 2.5 years following surgery (99, 101, 104, 105, 112, 117). Regarding regional changes in BMD, some case series have reported significant reductions in measures of femoral neck and total hip BMD collected at 12 months, ranging from 0.06 to 0.08 g/cm^2, as well as in lumbar spine BMD, ranging from 0.02 to 0.05 g/cm^2 (101, 104, 116, 118), while others reported no change (99, 104, 117, 118). The conflicting data on changes in measures of BMD following restrictive bariatric surgery might be explained by different factors related to the different samples studied, including amount and rapidity of weight loss, nutritional deficiencies and use of nutritional supplements, levels of PA, as well as the effects of different hormones on bone metabolism and type of bone (i.e. cortical or trabecular), and inaccuracy related to DXA measures on people who are morbidly obese during weight loss (335, 339).

Although several studies have investigated the effect of restrictive bariatric surgery on weight, there is less attention on its effects on body composition and BMD. Specifically, studies that have assessed body composition changes following restrictive bariatric surgery have typically used BIA, and those that have used DXA have focused exclusively on people who underwent LAGB and were limited to female samples. Additionally, conflicting data have been reported, particularly on the post-surgery changes in regional measures of BMD.

2.3.4 Cardiovascular fitness

Little attention has been given to the effect of restrictive bariatric surgery on cardiovascular fitness, also referred to as cardiorespiratory fitness or aerobic fitness. The investigation of the influence of LAGB and LSG on cardiovascular fitness is relevant since impairments in this outcome seem to be common among people who are obese (76-79, 85). Poor cardiovascular fitness is an important predictor of mortality and was found to be associated with increased short-term complications following bariatric surgery (340-342). Additionally, people who are obese and have low cardiovascular fitness may lack the capacity to engage in PA, particularly of moderate to vigorous intensity (76-80). The optimal method for the assessment of cardiovascular fitness in people who undergo bariatric surgery has not yet been established, and both maximal and submaximal exercise tests have been used in studies of bariatric surgery (82, 84, 85, 343-346). The presence of biomechanical limitations caused by obesity (e.g. gait limitations), as well as obesity-related comorbid conditions (e.g. hypertension) may affect people's ability and/or willingness to perform exercise tests (86, 347). Assessment using maximal exercise tests may be influenced by people's inability or unwillingness to exercise until exhaustion, and submaximal tests that require walking, such as the six-minute walking test, may be limited by slow walking speed and gait limitations that are often found in the obese population (86, 348). Submaximal exercise tests using cycle ergometers have been used to assess cardiovascular fitness of people who are obese, and seem to be the most appropriate tests for use in the bariatric surgery population, since the use of a cycle ergometer provides a weight-supported activity that can reduce the strain on joints, as well as the influence of gait limitations on the participant's performance (347, 349).

To date, no studies have compared the effects of restrictive bariatric surgery with non-surgical weight loss treatments on measures of cardiovascular fitness. Maximal and submaximal exercise tests have been used to investigate changes in cardiovascular fitness following malabsorptive or mixed bariatric procedures (343-346). The four case series that assessed the effect of restrictive bariatric surgery on cardiovascular fitness have reported inconsistent findings, with two studies reporting significant improvement (82, 85) and two reporting no changes (83, 84) in measures of cardiovascular fitness. Maniscalco et al. (82) followed 15 people and found a significant increase of 150 m (from 476 m to 626 m) in the six-minute walk distance at 12 months following LAGB. A recent study followed 1,205 people and found significant improvements in the time to complete a 400 metre walking test (382 to 340 seconds) and in resting heart rate (79 to 71 beats/min) at 3 years following different surgical procedures (70% RYGB and 25% LAGB) (85). In contrast, a study of 18 people who underwent either RYGB (n = 16) or LSG (n = 2) reported no change in peak oxygen uptake measured during a maximal exercise test, performed on a cycle ergometer, at 28 months post-surgery (83). Similarly, a study of 30 people who underwent LSG found no changes in cardiovascular fitness measured by the six-minute walk distance at 7 months post-surgery (84). The inconsistent results might be explained by the varied sample sizes and heterogeneous samples included in the studies, different assessment methods used and diverse follow-up periods.

Despite the importance of investigating the effects of bariatric surgery on cardiovascular fitness, only a small number of studies have measured change in this outcome following LAGB and LSG. Furthermore, no studies have used an outcome measure that is minimally affected by slow walking speed and gait limitations, such as a submaximal exercise cycle test, in order to assess changes in cardiovascular fitness following restrictive bariatric surgery.

2.3.5 Sleep problems

There are limited data on the effect restrictive bariatric surgery has on sleep disordered breathing (i.e. OSA), sleep quality, and daytime sleepiness. Obstructive sleep apnoea has been associated with impaired cardiovascular function, poorer HRQoL, increased risk of post-surgery complications, and found to be an independent prognostic marker of all-cause mortality in the general obese population and people scheduled to undergo bariatric surgery (i.e. candidates for bariatric surgery) (93, 350-352). The assessment of sleep quality and daytime sleepiness also seems relevant to people who undergo bariatric surgery, since complaints of poor sleep quality and excessive daytime sleepiness are common among people who are obese, with or without OSA (96, 353), and shorter sleep duration (i.e. < 7 hours) has been associated with increased weight and less weight loss (354, 355).

The gold standard diagnostic method for OSA is an overnight polysomnography, which involves the objective monitoring of a person’s sleep overnight in a medical facility (356, 357). During an overnight polysomnography, several physiologic measures are recorded, including airflow, finger pulse oximetry, respiratory effort, electrocardiogram, electroencephalogram, electrooculogram, chin and leg electromyograms, and body position (357). The main measurement made is the AHI, which represents the frequency of apnoea and hypopnoea events per hour of sleep. A diagnosis of OSA is made when someone has an AHI ≥ 5 in conjunction with symptoms of sleep disturbance (356, 357). However, the use of polysomnography to measure AHI is expensive, as it requires trained personnel and the use of a medical facility overnight (355, 357). As an alternative to a full overnight polysomnography, home monitoring with portable devices, such as the ApneaLink (ResMed Ltd, Bella Vista, NSW, Australia), is also considered an acceptable objective measurement. The ApneaLink is a portable single-channel recording device that has been considered valid and reliable to detect apnoea and hypopnoea events, when compared to an overnight polysomnography (358-361). In the general population and people who undergo bariatric surgery, the impact of sleep problems has also been evaluated using validated scales and/or questionnaires to assess sleep quality and daytime sleepiness. These include the Pittsburgh Sleep Quality Index (PSQI) (89, 96, 362-364), and the Epworth Sleepiness Scale (ESS) (357, 365).

The only RCT that used polysomnography to compare the effect of restrictive bariatric surgery and a non-surgical weight loss treatment (i.e. dietary, exercise, and behavioural interventions) on OSA found significant reductions in the mean AHI in both the LAGB group (-26 events/hour; 95% CI, -37 to -14) and the non-surgical group (-14 events/hour; 95% CI, -25 to -3), with a between-group difference of −12 events/hour (95% CI, −28 to 5) (317). Several case series of restrictive bariatric surgery have reported sustained improvement and/or resolution of OSA, in as many as 86% of participants (94, 97, 124, 132, 140, 149, 156, 366-374). However, most studies in this area rely on self-report of improvements in this condition with very few studies collecting objective measures of AHI (374). Nevertheless, the few studies that have collected objective data corroborate these findings. Specifically, a recently published case series of 36 participants which investigated the effects of LSG on OSA, measured using polysomnography, reported a reduction in AHI of 27 events/hour (from 33 events/hour to 6 events/hour; $p < 0.001$) 5 years post-surgery (98).

Few case series have investigated sleep quality (93, 96) and daytime sleepiness (93-95, 97, 98) following restrictive bariatric surgery. The only two case series that investigated sleep quality following restrictive bariatric surgery reported improvements in sleep quality and duration in this population (93, 96). Only one of the two case series used a validated measure of sleep quality and found a significant reduction of 4.2 points in the PSQI score (from 8.8 points to 4.6 points) and an increase in self-reported sleep duration (from 6.0 hours to 6.8 hours) at 3 to 12 months following LSG (96). All case series that have investigated changes in daytime sleepiness have reported significant improvements in this outcome post-surgery among samples with diagnosed severe OSA (93-95, 97, 98). The most recent case series of people undergoing LSG found that 92% of participants had a significant reduction in daytime sleepiness of 9.7 points in the ESS score (from 16.8 points to 7.1 points) at 5 years following surgery (98).

Overnight polysomnography and portable monitors to measure apnoea and hypopnoea events are considered to be valid objective measures for the assessment of OSA. Significant post-surgery improvement and/or resolution of OSA have been consistently reported. Although a small number of studies have reported improvements in sleep quality and daytime sleepiness following restrictive bariatric surgery, the use of validated outcome measures was inconsistent and samples were limited to people with severe OSA. Therefore, there is a need for further studies to assess the effect of surgery on these outcomes using validated measures, such as the ESS and PSQI, among representative samples of people undergoing LAGB and LSG. Furthermore, despite evidence to show that improvements in sleep problems accompany weight loss, there are no studies investigating the pattern of change in these outcomes during the first 12 months following restrictive bariatric surgery, which is the period were the majority of weight loss and improvement in obesity-related comorbid conditions are expected. This information is relevant to inform both patients and clinicians on the expected time course of change in these outcomes following surgery.

2.3.6 Health-related quality of life

The investigation of the effects of restrictive bariatric surgery on HRQoL is of importance, since impaired HRQoL is commonly found among candidates for bariatric surgery and is a motivating factor for seeking treatment with bariatric surgery (152, 153). Several instruments are available to assess both generic HRQoL and obesity-related quality of life. The Medical Outcomes Study Short Form 36 General Health Survey (SF-36) appears to be the most commonly used generic instrument in studies of bariatric surgery (150, 151). When compared to generic HRQoL measures, fewer studies have investigated changes in obesity-related quality of life. The short version of the Impact of Weight on Quality of Life (IWQOL-Lite) and the Moorehead-Ardelt Quality of Life Instrument appear to be the obesity-related instruments most frequently used (150). The choice of either generic or condition-specific instruments to assess quality of life depends on the purpose of the study. For instance, the use of generic HRQoL instruments in bariatric surgery studies allows for comparison between HRQoL of people who undergo bariatric surgery with other populations, while the use of obesity-related instruments may provide greater content validity, measure only the impact of obesity on various aspects of quality of life, and have greater sensitivity to detect post-surgery changes among people who undergo bariatric surgery (150, 151, 314).

Several RCTs and non-randomised controlled trials have compared the effects of restrictive bariatric surgery with non-surgical weight loss treatments (315, 317-319, 322). When compared to non-surgical weight loss treatments, most studies have reported a greater improvement in HRQoL measures following restrictive bariatric surgery. A recent non-randomised controlled trial found significantly greater improvements in HRQoL, assessed using the SF-36, in the LSG group, when compared to the non-surgical group (i.e. low calorie diet and DM2 medication) (322). Compared with baseline measures, 6 months following LSG, the physical component summary (PCS) score had improved by 9.8 points (from 46.4 to 56.2). The magnitude of this change was 5.6 points greater than the 4.2 points change found in the non-surgical group (from 50.7 to 54.9). The LSG group also presented a significant increase of 6.7 points in the mental component summary (MCS) score (from 48.3 to 55.0). The magnitude of this change was 6.1 points greater than the 0.6 points change found in the non-surgical treatment group (from 50.9 to 51.5). Additionally, although the between-group differences were not reported, the LSG group had significant increases in the domains of physical functioning, role-physical, general health, vitality, social functioning, and mental health, while on the non-surgical group, significant increase was only found on the physical functioning domain score (322).

Case series of restrictive surgery have consistently reported improvements on HRQoL and obesity-related quality of life, particularly in measures related to physical health, with post-surgery scores reaching similar values of those from the general population normative values, at follow-up periods up to 5 years post-surgery (66, 129, 134, 141, 154-175). A recent case series of 230 people undergoing LAGB reported significant increases in all domains and summary scores of the SF-36 at 12 months, with post-surgery scores similar to the general population normative values, which were maintained up to 3 years following surgery (174). At 12 months, there was a significant increase of 27.3 points in the PCS score and 22.9 points in the MCS score, as well as significant increases ranging from 5.3 to 57.4 points in all individual domains of the SF-36. Similarly, a recently published case series of people undergoing LSG reported significant improvements in HRQoL and obesity-related quality of life, assessed using the SF-36 and the Moorehead-Ardelt Quality of Life Instrument, respectively (170). At 12 months post-surgery, there were increases in all domains of the SF-36, ranging from 10.6 to 22.2 points, with values reaching those of the general population normative values. When assessed by the Moorehead-Ardelt Quality of Life Instrument, all participants presented improvements and were classified as having good or very good obesity-related quality of life at 12 months following LSG (170).

Improvements in generic and obesity-related quality of life have been consistently reported following bariatric surgery (152, 153, 375, 376). Few studies have investigated changes in HRQoL following restrictive bariatric surgery using both generic and obesity-related quality of life instruments. The use of both generic and obesity-related instruments may provide more robust data on post-surgery changes in HRQoL (153, 314). This is because the use of generic instruments would allow comparisons of post-surgery values with normative population values, while the use of obesity-related instruments may be sensitive to change in aspects particularly relevant for people who are obese who have chosen to undergo restrictive bariatric surgery. Additionally, although there are some data to suggest that improvements in HRQoL occur mostly over the first 12 months following restrictive bariatric surgery (158, 160, 174, 377), little is known regarding the pattern of change in generic and obesity-related quality of life over this period. This information is of importance to inform both patients and clinicians on the expected time course of change in these outcomes following surgery.

2.3.7 Mental health

There are limited data on the effect of restrictive bariatric surgery on symptoms of different mental health disorders. The investigation of the effect of surgery on symptoms of mental health disorders, such as depression and anxiety is relevant since they have been shown to be prevalent among candidates for bariatric surgery and associated with worse post-surgical outcomes (190, 378, 379). Further, there is evidence to show an association between obesity and increased symptoms of stress (179, 180). Changes in mental health outcomes have been assessed via self-reports of a mental health disorder diagnosis, structured diagnostic clinical interviews, and commonly used validated self-reported questionnaires, such as the Beck

Depression Inventory (BDI) and the Hospital Anxiety and Depression Scale (168, 187, 380).

To date, no studies have compared the specific effects of restrictive bariatric surgery with non-surgical weight loss treatments on symptoms of mental health disorders. Several case series of LAGB and LSG have reported significant reductions in symptoms of depression at follow-up periods up to 5 years (154, 156, 162, 167, 168, 181-191). The case series of people undergoing LAGB with the largest sample size (n = 487) reported a significant reduction in symptoms of depression of 9.9 points in the BDI score (from 17.2 points to 7.8 points) at 12 months, which was maintained up to 4 years (181). The most recent study that investigated the effect of restrictive bariatric surgery (i.e. LAGB and LSG) on symptoms of mental health, using the Hospital Anxiety and Depression Scale, found that when compared to the pre-surgery depression subscale score, there was a significant reduction of 3.0 points at 12 months (from 7.3 points to 4.3 points), which was maintained up to 4.5 years post-surgery (167).

Fewer case series have investigated changes in symptoms of anxiety following restrictive bariatric surgery. Findings from these case series showed significant reductions in symptoms of anxiety up to 12 months post-surgery, but inconsistent findings have been reported regarding the long-term maintenance of such reductions (154, 167, 182-184, 188). The case series of people undergoing LAGB with the longest follow-up period found a significant reduction of 2.1 points (from 9.5 points to 7.4 points) in the Hospital Anxiety and Depression Scale anxiety subscale score at 3 years, which was maintained up to 6 years following surgery (183). In contrast, the most recent study that investigated changes in symptoms of anxiety following restrictive bariatric surgery (i.e. LAGB and LSG), reported that the significant reduction of 1.2 points (from 6.7 points to 5.5 points) in the Hospital Anxiety and Depression Scale anxiety subscale score found at 12 months was not maintained up to 4.5 years post-surgery (167). A suggested reason for the inconsistent findings regarding maintenance of reductions in symptoms of anxiety found post-surgery is that symptoms of anxiety seem to be less related to weight loss when compared to those of depression, and therefore influenced by other factors not related to surgery (167, 184).

The only study that investigated the effects of restrictive bariatric surgery on symptoms of stress reported a significant reduction in the stress module score of the

Patient Health Questionnaire at 12 months following LSG; however, the magnitude of change was not reported (186).

There is evidence to suggest that the majority of improvement in symptoms of mental health disorders occurs in the first 12 months following restrictive bariatric surgery, when the majority of weight lost occurs, and that there is either maintenance of (182, 183) or a reduction in the improvement after the first post-surgery year (167, 168, 191, 381). Despite findings that indicate the majority of improvement in symptoms of mental health disorders occurs in the first 12 months following restrictive bariatric surgery, the pattern of change during this period, and consequently, the expected time course of change in these outcomes are still unknown. Additionally, when compared to symptoms of depression, changes in symptoms of anxiety have been investigated by fewer studies, particularly of LSG (167, 183). Finally, despite evidence that suggests a relationship between obesity and stress, and a favourable effect of surgery on perceived stress, there is a lack of studies that have investigated the effect of restrictive bariatric surgery on symptoms of stress (180, 186).

2.3.8 Summary

There is data to show that restrictive bariatric surgery results in significant and sustained weight loss, improvement and/or resolution of obesity-related comorbid conditions, as well as significant improvements in generic and obesity-related quality of life and symptoms of mental health disorders. However, little attention has been given to the influence of LAGB and LSG on other health outcomes relevant to people’s participation in PA, including cardiovascular fitness, sleep quality, daytime sleepiness, body composition and BMD. Additionally, most studies have not assessed temporal changes in different health outcomes following restrictive bariatric surgery, particularly during the first 12 months following the procedure, when the majority of weight loss is expected to happen. The assessment of the pattern of change in different health outcomes post-surgery is relevant to inform both patients’ expectations of change and clinicians’ decision making regarding optimal post-surgical management (12-15, 153).

2.4 Physical activity and sedentary behaviour

This section provides an overview of definitions and recommendations regarding PA and SB, as well as a summary of the different available methods to measure PA and SB. A discussion of the health implications of PA and SB is also provided.

2.4.1 Definitions and recommendations

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure above resting levels (50). It comprises exercise, sports, and PA done as part of daily living, occupation, leisure, and transportation (50). Physical activity can be classified as light, moderate or vigorous in intensity based on differences in energy expenditure (382). Energy expenditure is often expressed as metabolic equivalent units (METs). One MET represents the energy expenditure required at rest, which is equivalent to 3.5 mL/kg/min of oxygen intake (42). Of note, studies have reported higher energy expenditure among obese people when compared to people in the normal weight range, which appears to be explained by a higher cost of activities due to the higher body weight, and suggests that in obese people, the value for one MET could be lower than 3.5 mL/kg/min of oxygen intake (383-385). Light intensity PA involves activities with an energy expenditure of 1.5 to < 3 METs (e.g. slow walking, showering or ironing while standing). Moderate intensity PA involves activities with an energy expenditure of 3 to < 6 METs (e.g. brisk walking, jogging). Vigorous intensity PA refers to activities with an energy expenditure ≥ 6 METs (e.g. running, cycling) (382, 386, 387). Sedentary behaviour is defined as activities performed during waking hours (i.e. excluding sleep) that involve low energy expenditure (i.e. < 1.5 METs), and are performed while in a sitting or reclining posture (45, 387). Television viewing, computer use, sitting, and lying down are common examples of SB, and occur across different domains, such as work, leisure, domestic, and transportation (45, 387).

Current international guidelines for the development and maintenance of health recommend that adults should engage, every week, in a minimum of 150 minutes of moderate to vigorous intensity PA (MVPA) or 75 minutes or more of vigorous PA, or an equivalent combination of both (50). The recommended amount of PA should be performed in bouts of at least 10 minutes, and it is preferable to accumulate the time spent in MVPA over five or more days each week (50). Since walking is considered a common way of accumulating PA, these recommendations have been translated to a daily step count (388). An average of 7,000 steps per day spent at a moderate to vigorous intensity, every day of the week, is considered to approach 150 minutes of MVPA per week (388). The most recent international guidelines recommend that for adults, between 150 and 250 minutes of MVPA per week should be accumulated to prevent weight gain and greater amounts (>250 minutes of MVPA per week) are needed for weight loss (51).

Since for most people, the majority of waking hours in a day is characterised by participation in SB and light intensity PA, regardless of meeting the guidelines for participation in MVPA, there has been increased interest in the health benefits of decreased time in SB and participation in light intensity PA (50, 389-391). Recently, guidelines on the recommended amounts of PA to maintain and improve health have included recommendations on the maximum amount of time adults should spend in SB to minimise the risk of deleterious health effects. Not only does total time spent in SB have a negative effect on health, but the way in which SB is accumulated also seems to be of importance (43, 54, 70). Current recommendations state that people should avoid prolonged periods of SB (i.e. sitting for more than 30 minutes), which can be achieved through breaking prolonged uninterrupted periods of SB as often as possible with light intensity PA (52-54). There is recent evidence to suggest that uninterrupted periods of ≥ 10 minutes spent in SB may be associated with deleterious health effects (392, 393). Previous studies have also found a strong relationship between SB and light intensity PA, which indicates that SB is likely to be replaced by light intensity PA (44, 394). Since SB appears to be mostly replaced by light intensity PA, studies have investigated possible health benefits of participation in light intensity PA and found reductions in CVD risk factors when SB is replaced by light intensity PA (46-49).

2.4.2 Measurement of physical activity and sedentary behaviour

The measurement of PA and SB can be achieved via subjective methods (e.g. surveys, questionnaires) or objective methods (e.g. pedometers, accelerometers). The choice of method to measure PA and SB is influenced by different factors, including characteristics of the population being studied, study design and aims, cost, need for technical expertise, as well as validity, reliability and responsiveness of the various methods (395, 396).

2.4.2.1 Subjective methods

Subjective methods involve asking people (or a proxy) to report PA and/or SB over a specified time period. Physical activity and SB surveys, diaries, logs, and questionnaires are extensively used due to the low cost, as well as speed and ease of application, particularly when data are collected for large epidemiological studies (396). In addition, subjective measures have the advantage of providing detailed information regarding the domain (e.g. occupational, leisure), type (e.g. watching television, reading), and reasons for participation in SB and PA (397). However, the use of subjective measures has some important limitations. For example, these methods rely on people's recall of activities which may introduce measurement error, particularly when asking children and elderly participants to recall how they spent their time. Measurement error is also likely to be greater when people are required to recall PA and SB over a longer period (e.g. a week versus the previous day) (398).

A systematic review of 173 studies that compared subjective (i.e. questionnaires, diary) and objective (i.e. pedometer, accelerometer) measurements of PA in adults found low to moderate correlations between these measurements, with a mean r value of 0.37 (399). Disparity between subjective and objective measures of PA has also been reported in people who are obese and those who undergo bariatric surgery. That is, studies that have compared subjective and objective measures of PA in obese populations report that obese adults often overstate the amount of PA they perform in daily life, particularly PA of vigorous intensity (5, 9, 400, 401). For example, a study that assessed changes in MVPA 6 months following bariatric surgery using self-reported (i.e. questionnaire) and objective (i.e. accelerometer) measures demonstrated a fivefold increase in self-reported amount of MVPA but no change in objective measures of MVPA (5). Overestimation of PA levels is common across many populations and may reflect problems with recall, however; there are two more potential reasons for the overestimation of PA levels among people who are obese. One reason is that the overestimation is likely to reflect social desirability bias, in that people who are obese are more likely to report engaging in healthy behaviours. Further, the overestimation of PA levels may also reflect a different perception of effort related to PA intensity, as people who are obese perceive activities to be of vigorous intensity more easily than normal-weight counterparts (71, 400, 401).

2.4.2.2 Objective methods

Given the error associated with subjective methods, objective methods are increasingly being used to assess PA and SB. Objective measures use motion sensors to detect body movement (e.g. pedometers and accelerometers) and/or physiological sensors to estimate energy expenditure (e.g. metabolic monitors) (402). When compared to subjective methods, these devices are more accurate in providing detailed measures of body movement and intensity of activities performed (399, 403). Different measures have been considered to be gold standards for assessment of PA and SB, according to the measurement purpose (397, 404, 405). For the measure of body motion, the gold standard is direct observation, which can be done by observers watching in person or by video recordings to quantify people's PA. For the measure of energy expenditure, the gold standard is doubly labelled water, an isotope-based technique to estimate carbon dioxide production in body fluid samples over a period of time (397, 404, 405). To date, the gold standard for measurement of SB has been direct observation or a combination of data from objective (e.g. accelerometer) and subjective measures (e.g. diary) (406). However, gold standard measures are usually intrusive on the person's privacy and time consuming (e.g. direct observation), or limited by the high cost, participant burden, and need of laboratory setting and technical expertise (e.g. doubly labelled water) (407). When compared to the gold standard methods, motion sensors (e.g. pedometers and accelerometers) and metabolic monitors provide an accurate and more accessible way to objectively measure PA and SB and energy expenditure, respectively (397, 404). Disadvantages common to most motion sensors and metabolic monitors are that they need to be removed during bathing and water activities and do not provide assessment of arm movement. Although motion sensors and metabolic monitors provide more accurate measures of PA and SB, when compared to subjective methods, the comparison of objective measures of PA and SB between studies that use different devices might be problematic. This is because the way in which these measures are estimated often differ according to the device used. That is, time spent in MVPA might be derived from energy expenditure when using a metabolic monitor (e.g. time spent in PA with an energy expenditure ≥ 3 METs), while the same measure of time spent in MVPA might be derived from the number of steps taken per time epoch (e.g. time spent in walking-based PA with a step cadence > 80 steps/minute) (7, 25). Additionally, the relationship between the ways in which a measure of PA is estimated (e.g. step count and energy expenditure) may differ between individuals and according to environmental factors. That is, in some circumstances, the same step cadence will require different levels of energy expenditure (e.g. a person with normal weight walking at 60 steps/minute on flat ground will expend less energy than an obese person walking at 60 steps/minute up a steep hill, into a head wind). Further, even when studies use identical devices to measure PA and SB, the estimates may be influenced by differences in data handling procedures, such as different wear time criteria used to consider the data valid (i.e. minimum number of days and of hours per day the device needs to be used) (23, 408-411). The following paragraphs provide a summary of the most common motion sensors and metabolic monitor used to objectively measure PA and SB.

Pedometers

Pedometers, also referred to as step counters, are simple, inexpensive devices (i.e. cost range from AUD$15 to AUD$300) that are commonly used to obtain objective measures of PA. They are most often worn on the hip via a waistband, and are designed to detect vertical movement during ambulation, through a horizontal, spring-suspended lever arm that deflects with vertical movement (408, 412). In addition to the disadvantages common to motion sensors in general, the use of pedometers has specific limitations, such as counting any vertical movement as a step (e.g. vibrations when driving a car or standing up from a sitting position); lack of information regarding the intensity at which activities are performed; and underestimation of step counts in populations who walk at low speeds (e.g. elderly and obese) (412-414). Since pedometers are usually worn around the waist or hips, an additional limitation among people who are obese is decreased accuracy due to pedometer tilt (415). Abdominal adipose tissue can cause a waistband-mounted pedometer to tilt and place it in a non-optimal position to detect vertical movement, which might affect its capacity to provide an accurate measurement of steps (397, 415). A new generation of pedometer has overcome some of these problems. The StepWatch 3 Activity Monitor (SAM) (Cyma Corporation; Seattle, WA, USA) is a micro-processor driven pedometer that responds to time, acceleration and position. It is worn on the right ankle, and has been shown to provide a valid and reliable count of steps in lean and obese adults, when compared to direct observation (416). The SAM records numbers of steps in one minute epochs, and cadence thresholds have been used to assess time spent in different intensities of walking-based PA (6, 7, 20). It has been used to quantify changes in PA in a large observational study (n = 310) involving people who underwent bariatric surgery (6, 7, 20).

Accelerometers and portable metabolic monitors

Accelerometers are generally small, lightweight devices that record body motion in one or more planes, and provide information regarding the amount and intensity of activities (395, 405). Portable metabolic monitors combine accelerometry data with non-invasive physiological sensors (e.g. body temperature and galvanic skin response) to provide an estimation of energy expenditure during different activities (417). Disadvantages common to most accelerometers and portable metabolic monitors are relatively high cost (i.e. AUD$700 to AUD$3,400) and the requirement of technical expertise to collect, manage and interpret the data collected (395, 396).

Some accelerometers and portable metabolic monitors classify time into SB, light, moderate and vigorous-intensity PA based on intensity of movement and, when available, measures of physiological responses (e.g. heart rate and skin temperature) (417). In studies of people who undergo bariatric surgery, the most commonly used accelerometer appears to be the RT3 (Stayhealthy; Monrovia, CA, USA), a tri-axial accelerometer, worn around the waist, that provides PA data as activity counts (21, 418). The most commonly used portable metabolic sensor in studies of bariatric surgery appears to be the SenseWear Armband (SAB) (Bodymedia Inc.; Pittsburgh, PA, USA). The SAB is a small, lightweight monitor that is worn over the triceps brachii muscle bulk of the left arm. Placement of this device on the arm eliminates issues related to non-optimal position to detect movement caused by abdominal fat when devices are worn around the waist (e.g. RT3 accelerometer) (23, 419). It combines a tri-axial accelerometer and non-invasive physiological sensors that detect heat flux, skin temperature and galvanic skin response to provide integrated measures of body motion and energy expenditure (23, 419). The SAB estimates energy expenditure and PA intensity using a proprietary algorithm and has been shown to provide valid measures and reliable measures in normal- and overweight adults, when compared to indirect calorimetry and doubly labelled water (420-422). It has also been used in studies that included people who are obese and those who underwent bariatric surgery (34, 40, 423).

Although a pattern of low levels of PA has been found among candidates for bariatric surgery, when compared to people in the normal-weight range (21-23), few studies have used objective methods to assess the influence of restrictive bariatric surgery on PA and SB levels. Furthermore, a combination of different devices (e.g. pedometers and accelerometers) might provide more robust data on patterns of accumulation of PA and SB (25). The combination of data from different devices in the same sample offers the combination of useful and easily interpreted measures, such as number of steps that can be translated into simple clinical messages, with more complex measures, such as energy expenditure that offer important details regarding the pattern of accumulation (i.e. bout-related PA and SB) and intensity of activities performed.

Objective measurement of bout-related physical activity and sedentary behaviour

When compared to subjective methods, the use of objective methods to assess PA and SB allows for more accurate, reliable and detailed measures of not only total time spent in SB and PA performed at different intensities, but also the accumulation of PA and SB in uninterrupted bouts of time (399, 403). The capacity to investigate patterns of accumulation of both SB and PA is important as this appears to influence health outcomes, independent of the total time spent in SB and PA, as described in sections 2.4.1 (Definitions and recommendations) and 2.4.3 (Health implications). The objective measurement of bout-related PA, particularly MVPA, in bouts ≥ 10 minutes has been well established in studies of normal-weight and obese adults (6, 7, 21, 424, 425). This is because the investigation of objectively-measured MVPA accumulated in uninterrupted bouts ≥ 10 minutes reflects current international guidelines, which recommend people to participate in a minimum of 150 minutes/week of MVPA in bouts ≥ 10 minutes in order to obtain health benefits (42, 50, 51).

In contrast with the bout duration for MVPA, less is known about the maximum bout duration in which SB can be accumulated without increasing the risk of deleterious health outcomes. Evidence from observational and experimental studies indicates that people should avoid prolonged uninterrupted periods of SB (i.e. sitting for more than 30 minutes), which can be achieved by breaking these prolonged periods as often as possible (43, 44, 53, 54, 70, 391). However, a recent cross-sectional study of adults in the general population that investigated the association between objectively-measured SB bouts of different durations (i.e. 1, 2 to 4, 5 to 9, 10 to 14, 15 to 19, 20 to 24, 25 to 29, and ≥30 minutes) and cardiometabolic risks has found that SB accumulated in bouts ≥ 10 minutes was associated with higher risk (i.e. increased waist circumference, triglycerides and high-density lipoprotein cholesterol) (392). Similarly, a cross-sectional study of adults with severe obesity that investigated the association between objectively-measured SB bouts of different durations (i.e. 1, ≥ 10 and ≥ 30 minutes) and cardiometabolic risk factors (i.e. diabetes, metabolic syndrome, elevated blood pressure and waist circumference) reported that measures of SB in uninterrupted bouts ≥ 10 minutes appear to be a more conservative estimate in order to identify prolonged periods of SB, when compared to bouts ≥ 30 minutes, and should be considered when using objective measures of SB (393).

2.4.3 Health implications

Several international societies advocate the importance of regular participation in PA due to its numerous physical and mental health benefits in adults (42, 50). In addition to the benefits associated with regular participation in PA, there are recent data to suggest that similar benefits, independent of participation in PA, can be achieved by decreasing time spent in SB (44, 426). The following sub-sections summarise the role that participating in low levels of PA and accumulating increased time in SB may have in the development of obesity and different comorbid conditions. Possible mechanisms are discussed. The implications of PA and SB within the context of bariatric surgery are also discussed.

2.4.3.1 Physical activity, sedentary behaviour and obesity

Several cross-sectional and longitudinal studies have shown that participation in low levels of PA is associated with increased body weight (427-433). A recent large cohort study (n = 17,394) investigated the association between low levels of PA (i.e. not meeting the guidelines of 150 min/week of walking, moderate and vigorous activity) and incident obesity in South Australian adults (433). When compared to people who met the guidelines for PA, those who did not had a relative risk for developing obesity of 1.5 (95% CI, 1.1 to 1.9). A large cross-sectional population-based study (n = 3,867) investigated the association between objective measures of PA and risk of being overweight (i.e. BMI ≥ 25 kg/m^2) or obese (i.e. BMI ≥ 30 kg/m^2) in adults (432). When compared to those in the most active quintile for PA, those in the least active quintile for PA had an odds ratio of 2.0 (95% CI, 1.7 to 2.5) for being overweight, and of 3.3 (95% CI, 2.5 to 5.0) for being obese.

Increased time in SB, independent of participation in PA, has also been associated with higher risk of obesity (434-439). Chau et al (439) reported associations between occupational and leisure-time sitting, PA, and obesity in 10,785 working adults. When compared with workers who had jobs characterised by long standing periods, and therefore considered to engage in less SB, those who had jobs characterised by long sitting periods had a relative risk for overweight or obesity of 1.1 (95% CI, 1.1 to 1.3). The increased risk for overweight or obesity in those who reported more occupational sitting was found to be independent of PA and leisure-time sitting. The same study showed that when compared to those who reported < 4 h/day, those who reported ≥ 4 h/day of leisure-time sitting had a relative risk of overweight or obesity of 1.3 (95% CI, 1.1 to 1.4). The increased risk of overweight or obesity for those who reported greater time spent in leisure-time sitting was found to be independent of PA and occupational sitting. The association between the development of obesity and participation in low levels of PA and increased time in SB can be explained by reductions in total energy expenditure and consequent positive energy balance. A positive energy balance, when energy intake is higher than energy expenditure, results in increased energy storage and, consequently, in increased body weight (432, 439, 440).

Physical activity and/or exercise also seem to play an important role in weight management and maintenance, as well as in body composition, especially in preserving FFM and reducing abdominal fat (51, 441-448). A large cohort study followed 3,554 people for 20 years and investigated the association between self-reported habitual PA and changes in weight and waist circumference (444). When compared to people who reported low levels of PA (i.e. those in the lowest tertile of PA), those who maintained high levels of PA (i.e. those in the highest tertile) over time gained less weight and fewer centimetres in waist circumference. A high quality RCT that investigated the effects of a 16-month supervised exercise intervention (i.e. walking on a treadmill for 45 minutes, 5 days/week), without diet modification, on body weight and composition of overweight adults found that the exercise group reduced or maintained weight, FM, and FFM (441). Specifically, their findings showed that in comparison to the control group (i.e. who received instructions to maintain usual PA and dietary intake throughout the study), men in the exercise group had significantly greater reductions in weight (5.2 kg; SD, 4.7), BMI (1.6 kg/m^2; SD, 1.4), and FM (4.9 kg; SD, 4.4). Women in the exercise group maintained weight, BMI and FM, while those in the control group had significant increases in weight (2.9 kg; SD, 5.5), BMI (1.1 kg/m^2; SD, 2.0), and FM (2.1 kg; SD, 4.8). Of note, men and women in the exercise group maintained their FFM and had significant reductions in abdominal fat (441).

2.4.3.2 Physical activity, sedentary behaviour and obesity-related comorbid conditions

2.4.3.2.1 Physical activity

Regular participation in PA, particularly MVPA, has been associated with reduced risk of developing different cardiometabolic conditions, such as DM2, CVD and associated risk factors (42). For example, a systematic review of 10 cohort studies indicated that both regular participation in MVPA and walking were associated with decreased risk of DM2 in adults (61). The relative risk of DM2 for those who reported participation in regular MVPA, when compared to low levels of PA, was 0.7 (95% CI, 0.6 to 0.8). Similarly, the relative risk of DM2 for those who reported regular walking, when compared to almost no walking, was 0.7 (95% CI, 0.6 to 0.8). A large cohort study followed 27,055 women for an average of 11 years and found that those who reported expending ≥ 1500 kilocalories per week on PA, when compared to < 200 kilocalories per week, had a hazard ratio of 0.6 (95% CI, 0.5 to 0.7) for CVD, and of 0.6 (95% CI, 0.5 to 0.7) for total, low-density lipoprotein, and high-density lipoprotein cholesterols (59). The associations between PA and risk of DM2, CVD and associated risk factors, such as blood lipids (i.e. triglycerides and cholesterol), blood pressure, and metabolic syndrome have been consistently shown to be independent of body weight and other relevant confounding factors, such as age, sex, smoking, alcohol use, medication use, family history of DM2, and risk factors for CVD (57-65, 294, 449-459). Participating in PA most likely reduces the risk of DM2 by decreasing insulin resistance and improving glycaemic control (57). Although the mechanisms by which participation in PA reduces the risk of CVD are not fully understood, improvements in endothelial function, as well as in CVD risk factors, such as blood pressure, lipid levels and glycaemic control seem to be the main contributors to the decreased risk of CVD (59, 460).

There is evidence to suggest that participation in PA has a beneficial influence on the prevalence, incidence and slowing of progression of musculoskeletal conditions such as osteoarthritis of the lower limbs and osteoporosis (461, 462). Evidence from cohort studies suggests that participation in PA, in the absence of previous injury, is associated with decreased risk of lower limb osteoarthritis and, when adopted as part of the management of osteoarthritis, results in beneficial effects on pain and function (461, 463-465). A large cohort study of Australian women (n = 3,613) found that when compared to women who reported no leisure-time PA, those who reported moderate levels of leisure-time PA (i.e. 75 to < 150 min/week of moderate intensity PA) had an odds ratio for osteoarthritis of 0.8 (95% CI, 0.7 to 0.9) (463). This association was found to be independent of body weight and other confounding factors (e.g. DM2, CVD, depression, and alcohol use) The suggested mechanisms by which participation in PA is associated with the management of osteoarthritis include the maintenance of muscle strength, joint range of motion, balance and fitness, which in turn result in reduction in joint pain and improvement in physical function (461, 465). Meta-analyses of RCTs and cohort studies have demonstrated beneficial effects of participation in PA on measures of skeletal health (i.e. BMD) and reduced risk of osteoporosis and fractures (466-472). The beneficial effects of weight-bearing and muscle-strengthening activities on BMD have been suggested as the mechanisms by which PA positively impact bone health (462, 473). Since BMD is a strong predictor of fracture risk, the reduction in fracture risk associated with PA is likely due to the capacity of PA to increase, or minimise the decrease in, BMD (42).

Several cross-sectional and cohort studies, as well as RCTs have reported on the association between participation in low levels of PA and increased symptoms of mental health disorders, such as depression and anxiety (474-483). Vallance et al (482) investigated the association between objective measures of PA, collected using the ActiGraph accelerometer, and symptoms of depression in 2,862 adults. When compared to people who spent > 36.0 min/day in MVPA, those who spent < 8.5 min/day in MVPA had an odds ratio for depression of 2.5 (95% CI, 1.4 to 5.0). This association was independent of body weight and other confounding factors (e.g. sex, age, smoking, education). A large population-based study (n = 41,914) reported that when compared to adults who reported at least 30 minutes of MVPA on at least 5 days/week, those who reported no participation in MVPA had an odds ratio for symptoms of depression of 1.2 (95% CI, 1.1 to 1.4) and for symptoms of anxiety of 1.3 (95% CI, 1.2 to 1.5) (476). The mechanisms by which PA is associated with lower risk of symptoms of mental health disorders are not fully known, and this association is likely to be explained by a complex interaction of psychological (e.g. increased self-efficacy, sense of mastery, and distraction) and neurobiological mechanisms (e.g. an increase in endorphins and norepinephrine, dopamine, and serotonin neurotransmitters, and changes in the hypothalamic adrenocortical system) (484).

In summary, there is strong evidence to show that regular participation in PA, independent of body weight, is associated with decreased risk of cardiometabolic, musculoskeletal and mental health conditions that are often comorbid with obesity. The association between participation in PA and decreased risk of comorbid conditions appears to be influenced by a complex interaction between biological (e.g. reduction in insulin resistance, improvement in endothelial function, and increase in different neurotransmitters), mechanical (e.g. increased weight-bearing and muscle-strengthening activities) and psychosocial factors (e.g. increased self-efficacy, and distraction).

2.4.3.2.2 Sedentary behaviour

Several cross-sectional and cohort studies have reported that increased time in SB, particularly when accumulated in prolonged uninterrupted periods, is associated with increased risk of DM2, CVD and cardiometabolic risk factors (32, 43, 64, 392, 393, 435, 458, 485-499). For instance, a meta-analysis of cohort studies reported an association between television viewing and risk of DM2, with a relative risk of 1.2 (95% CI, 1.1 to 1.3) per 2 h/day of television viewing (494). Findings from a systematic review of cohort studies showed that for a 2-hour increase in screen time activities, the hazard ratio for cardiovascular events was 1.2 (95% CI, 1.1 to 1.2), and for a 2-hour increase in sitting time the hazard ratio for cardiovascular events was 1.1 (95% CI, 1.0 to 1.1) (496). A large cross-sectional study of adults in the general population (n = 5,917) has suggested that SB was associated with increased cardiometabolic risk factors (392). Findings consistently showed that SB accumulated in bouts ≥ 10 minutes were significantly associated with increased waist circumference, triglycerides and high-density lipoprotein cholesterol. A recent cross-sectional study (n = 927) investigated the relationship between objectively-measured SB and cardiometabolic risk factors in people with severe obesity before bariatric surgery (393). The results showed that one hour per day of SB accumulated in uninterrupted bouts ≥ 10 minutes was significantly associated with higher odds of diabetes (odds ratio, 1.2; 95% CI, 1.1 to 1.3), metabolic syndrome (odds ratio, 1.1; 95% CI, 1.0 to 1.2) and elevated blood pressure (odds ratio, 1.1; 95% CI, 1.0 to 1.3). The associations reported in these studies were found to be independent of body weight, participation in MVPA, and other confounding factors such as age, sex, smoking, alcohol use, family history of DM2, risk factors for CVD, and dietary factors. In contrast, other studies have found no association between SB and cardiometabolic risk factors after controlling for time spent in MVPA (489, 492, 498). A cross-sectional study of 370 adults characterised by high levels of objective measured total and bout-related MVPA reported that the association found between SB and cardiometabolic risk factors was no longer statistically significant after controlling for time spent in MVPA (498). A possible explanation for the contradictory findings in the study by Scheers et al. (498) regarding the independent association between time in SB and cardiometabolic risk may be that the effects of SB on cardiometabolic health are reduced by high levels of MVPA (500). This explanation is supported by data from a recent meta-analysis of 13 prospective cohort studies (n = 1,005,791) that investigated the association between measures of PA and SB and mortality (i.e. all-cause, cardiovascular disease and cancer-related mortality) (501). The findings showed no association between daily sitting time and mortality for participants in the most active quartile of PA. Specifically, for those who were grouped into the highest quartile for PA (3.5. MET-h/week) there was no difference in mortality risk between those who also sat for more than eight hours per day and those who sat for less than hour days per day. However, for those who were grouped into the lowest quartile of PA (i.e. < 2.5 MET-h/week) who also sat for less than four hours per day, there was an increased risk of dying (hazard ratio, 1.3; 95% CI, 1.2 to 1.3) (501). The association between increased time in SB and higher risk of DM2 and CVD, independent of PA levels, appears to be mediated by the effects of SB in reducing the levels of skeletal muscle lipoprotein lipase (502, 503). The skeletal muscle lipoprotein lipase is an enzyme that facilitates the uptake of free fatty acids into skeletal muscle and adipose tissue, and low levels of skeletal muscle lipoprotein lipase have been associated with decreased insulin sensitivity, plasma glucose intake, and high-density lipoprotein cholesterol, as well as with increased triglycerides levels and risk of CVD.

There is a scarcity of studies that investigated the associations between SB and musculoskeletal conditions. However, there is some evidence to suggest that prolonged periods spent in SB, independent of MVPA, are associated with reduced BMD (504, 505). The association between SB and BMD appear to be explained by changes in bone metabolism due to decreased muscle activation and unloading of bone structure. Sedentary behaviour, particularly sitting, may result in increased bone reabsorption and decreased stimulation of bone formation, which consequently leads to reduced BMD and increased risk of osteoporosis (503).

Various cross-sectional and cohort studies, as well as RCTs and non-randomised controlled trials have shown that increased time in SB, independent of participation in MVPA, is associated with increased symptoms of mental health disorders, such as depression and anxiety (482, 506-511). A recent study investigated the association between objective measures of SB, collected using the ActiGraph accelerometer, and symptoms of depression and anxiety in a representative sample of the general population (509). When compared to people in the lowest tertile of sedentary time, those in the highest tertile had a higher risk of having symptoms of depression and anxiety (odds ratio, 1.7; 95% CI, 1.1 to 2.8). This association was found to be independent of participation in MVPA and socio-demographic factors. Although the mechanisms involved in the association between increased time in SB and increased symptoms of mental health disorders are still unknown, possible explanations include the displacement of light intensity PA caused by increased SB, the effects of SB (e.g. television viewing) on central nervous system arousal, sleep disturbances, poor metabolic health, as well as social withdrawal related to activities such as television viewing and computer use (507, 511).

In summary, several studies have established the association between increased time in SB and increased risk of comorbid conditions. In several studies, these associations have been shown to be independent of body weight and participation in MVPA. Of particular note is that the effects of SB appear to be independent of participation in MVPA. That is, the deleterious effects of increased time in SB may not be offset by participation in MVPA, particularly for those people who participate in low levels of MVPA. The association between increased time in SB and increased risk of comorbid conditions is complex and likely to be explained by interrelationships between biological (e.g. reduction in skeletal muscle lipoprotein lipase levels and central nervous system arousal), mechanical (e.g. decreased muscle activation) and psychosocial factors (e.g. social withdrawal).

Together, a pattern of both low levels of PA and increased time spent in SB involve interactions between different biological, mechanical and psychosocial factors in complex interactions that may result in further impairments in cardiovascular fitness (512-515) and HRQoL (516-518). People who participate in low levels of PA and increased time in SB, independent of body weight, have an increased risk of both all-cause and cause-specific mortality that might be explained by the presence of different comorbid conditions and impairments of cardiovascular fitness and HRQoL (31-33, 494, 519-522). Although obesity is an important risk factor for the development of the different comorbid conditions discussed in this section (i.e. DM2, CVD, musculoskeletal conditions, and symptoms of mental health disorders), it is unlikely that weight loss would mitigate the detrimental effects of participation in low levels of PA and increased time in SB, since the associations between little PA and increased SB with different comorbid conditions are independent of body weight. Therefore, regardless of body weight, in order to improve health, it is important to promote both an increase in participation in PA and a reduction in time spent in SB.

2.4.3.3 *Physical activity, sedentary behaviour, weight loss and obesity-related conditions within the context of bariatric surgery*

Different cross-sectional studies and case series of people undergoing bariatric surgery, mostly malabsorptive or mixed procedures, have reported that participation in PA results in better post-surgery outcomes, such as greater weight loss (66-68, 419, 523-526), favorable changes in body composition (527), greater reduction in risk factors for CVD (e.g. blood lipids) (528), and better HRQoL (66). Regarding weight loss, Bond et al (66) assessed the association between changes in subjectively-measured PA, using the International Physical Activity Questionnaire, and weight loss following RYGB. At 12 months post-surgery, when compared to people who reported participation in low levels of PA (i.e. < 200 min/week of PA), those who reported participation in higher levels of PA (i.e. ≥ 200 min/week of PA) had significantly greater weight loss, expressed in absolute weight (52.5 kg versus 46.4 kg) and BMI (18.9 kg/m^2 versus 16.9 kg/m^2). A cross-sectional study found that objective measures of MVPA, collected using the SAB, were associated with greater %EWL between 2 to 5 years following RYGB (419). When compared to those who participated in < 150 min/week of MVPA, those who participated in ≥ 150 min/week of MVPA had a greater %EWL (68% versus 52%; $p = 0.01$). In contrast to reports of people who underwent RYGB (66, 419, 523, 525), a study that investigated people who underwent LAGB found no associations between subjective measures of PA, collected using the International Physical Activity Questionnaire, and measures of weight loss (i.e. absolute weight, BMI, and %EWL) at 3, 6, and 12 months post-surgery (526). The inconsistent results may be explained by a slower weight loss found following LAGB when compared to RYGB, as well as by inaccurate measurement of PA by subjective methods.

The only study that investigated the association between subjective measures of PA, collected using the Modifiable Activity Questionnaire, and measures of body composition, using DXA, found that increased leisure-time PA was associated with favorable changes in body composition following RYGB (527). At 12 months, leisure-time PA was positively associated with LBM (r = 0.20) and negatively associated with FM (r = -0.20). Regarding risk factors for CVD, a case series that investigated subjectively-measured PA, using the Modifiable Physical Activity Questionnaire, found that when compared to people who reported participation in low levels of PA (i.e. energy expenditure <1,250 METs/14 days), those who participated in higher levels of PA (i.e. energy expenditure ≥ 1,250 METs/14 days) had favourable changes in blood lipids following LSG (528). At 12 months, despite similar weight loss, those who reported participation in higher levels of PA had lower levels of total cholesterol (182.8 mg/dL versus 220 mg/dL) and low-density lipoprotein cholesterol (103.2 mg/dL versus 133 mg/dL). Bond et al (66) also assessed the relationship between changes in subjectively-measured PA, using the International Physical Activity Questionnaire, and HRQoL, using the SF-36, following RYGB. At 12 months, when compared to people who reported participation in low levels of PA (i.e. < 200 min/week of PA), those who reported participation in higher levels of PA (i.e. ≥ 200 min/week of PA) had significantly greater weight loss and improvements in the scores of the MCS, as well as general health, vitality, and mental health domains of the SF-36.

Recently, a RCT of people who underwent RYGB, has reported positive effects of a post-surgery exercise training protocol on different outcomes (37, 529, 530). Coen et al (37) performed a RCT of people within one to three months following RYGB and found that when compared to a health education control group (n = 62), those who were randomly allocated to a 6-month semi-supervised moderate exercise intervention (n = 66) had significantly greater improvements in measures of insulin sensitivity and glucose effectiveness (i.e. the ability of glucose per se to stimulate glucose uptake). Additionally, when compared to the control group, the exercise group had a significantly greater improvement in peak oxygen uptake measured during a maximal exercise test, performed on a cycle ergometer. Data collected in a sub-sample of participants from the RCT by Coen et al (37), who completed the study and underwent muscle biopsy showed that the exercise group (n = 50) had favourable changes in measures of skeletal muscle mitochondria and intramyocellular lipids, when compared to no changes in the control group (n = 51) (529). Further, Woodlief et al. (530) reported findings from a post hoc analysis of participants from the same study, who were grouped according to the amount of recorded exercise. Participants in the exercise group (n = 56) were grouped according to the mean amount of weekly exercise performed, as either low (54 minutes/week; SD 8), middle (129 minutes/week; SD 4), or high exercise (286 minutes/week; SD 40), and compared to the control group (n = 42). This analysis showed that, when compared to the control group, both middle and high exercise sub-groups had significantly greater improvements in insulin sensitivity. However, only the high exercise sub-group had significantly greater weight loss, decrease in fat mass and abdominal fat, and improvements in cardiovascular fitness and skeletal muscle mitochondrial capacity (530). The findings of this RCT suggest that when compared with a health education control, an intervention involving semi-supervised moderate exercise results in greater improvements in post-surgery outcomes, such as cardiometabolic risk factors and cardiovascular fitness. Further, when the amount of weekly exercise performed was considered, a modest amount of exercise appears to provide additional improvements in insulin sensitivity following RYGB, however, higher volumes of exercise are needed to induce additional weight loss, changes in body composition, and improvements in cardiovascular fitness and skeletal muscle mitochondrial capacity.

Regarding SB, one case series and one cross-sectional study have reported inverse associations between subjectively-measured SB and measures of weight loss (525, 527) and body composition (527) following RYGB. A cross-sectional study that investigated the association between subjectively-measured SB, using self-reported occupational and leisure sitting time, and weight loss at 2 to 6 years post-surgery reported that when compared to people in the lowest tertile of sitting time, those in the highest tertile of sitting time had an odds ratio of 2.9 (95% CI, 0.1 to 5.7) for weight loss, and of 4.9 (95% CI, 0.6 to 9.3) for %EWL (525). These associations were independent of participation in PA. Vatier et al (527) investigated the association between subjectively-measured SB, using the Modifiable Activity Questionnaire, and measures of body composition, using DXA. At 12 months post-surgery, television watching time was significantly negatively associated with LBM (r = -0.21) and positively associated with FM (r = 0.23). The relationship between decreased time in SB and body composition measures was independent of leisure-time PA.

2.4.4 Summary

International guidelines provide clear recommendations regarding the minimum amount of MVPA that is required to improve and maintain health (50). More recently, there are data to suggest that participation in prolonged periods of SB is associated with deleterious effects on general health (43, 70, 531). Breaks in SB are likely to represent an increase in time spent in light intensity PA, which has also been found to be associated with better health outcomes (46, 502). There are several subjective and objective methods for the measurement of PA and SB (397). The objective methods for assessment of PA and SB (e.g. accelerometers and portable metabolic monitors) have been shown to be more accurate and reliable than subjective methods (e.g. questionnaires and diaries) (397, 402). Earlier research has established the associations between poorer health outcomes and a lifestyle of participation in low levels of PA and increased time in SB (44, 532-534). Of note, studies show that the detrimental effects of increased time in SB are not fully offset by participation in MVPA (43, 496). Low levels of PA, as well as high levels of SB were found to be independently associated with higher risk of obesity and different comorbid conditions, which suggests that promoting reductions in time spent in SB may be as important as increasing PA levels as a strategy to prevent obesity and improve health in adults (47, 437, 439). Additionally, there is early evidence to suggest that PA and SB may be important considerations in the bariatric surgery population, since increased participation in PA and decreased time in SB have been associated with better post-surgery outcomes (37, 66, 68, 419, 523, 525-530, 535).

2.5 Physical activity and sedentary behaviour prior to and following bariatric surgery

As the programme of research described in this thesis focuses on surgical treatment of obesity, the evidence for the effects of bariatric surgery, particularly LAGB and LSG, on different health outcomes (e.g. weight-related measures, obesity-related comorbid conditions, body composition and BMD, cardiovascular fitness, sleep problems, HRQoL, and symptoms of mental health disorders) was previously summarised in section 2.3 (Influence of restrictive bariatric surgery on health outcomes). This section provides information on PA and SB in people pre- and post-surgery. Given the bias associated with measuring PA and SB using subjective methods, only studies that have measured these variables using objective methods will be discussed. The studies first described are those which assessed PA and SB in candidates for bariatric surgery. Thereafter, studies are described in which PA and SB levels were assessed following bariatric surgery. Finally, studies that investigated the pre- to post-surgery changes on PA and SB measures are reviewed.

Several studies have demonstrated that candidates for bariatric surgery engage in little PA and spend most of their waking hours in SB (20-24, 27). The first study to investigate objective measures of PA in a large sample (n = 757) pre-surgery used the SAM, a micro-processor driven pedometer (20). Their findings showed that participants performed an average of 7,569 steps/day, with 54% of participants classified as sedentary (i.e. < 5,000 steps/day) or low active (i.e. 5,000 to 7499 steps/day) and only 20% classified as active (i.e. ≥ 10,000 steps/day). Similarly, a recent study that used the SAB, a portable metabolic monitor, found that candidates for bariatric surgery (n = 71) averaged 7,140 steps/day, and 59% of participants were classified as sedentary or low active and 18% were classified as active (27). There are also data to suggest that the participation in PA among people scheduled to undergo bariatric surgery is lower that the participation in PA in the general population. The only study that compared the levels of PA of 38 candidates for bariatric surgery to 20 normal-weight controls, using the RT3 accelerometer, found candidates for bariatric surgery to be less active than controls (21). When compared to controls, candidates for bariatric surgery had significantly fewer activity counts per hour (13,799 counts/hr versus 19,462 counts/hr) and spent less time engaged in MVPA (26.4 min/day versus 52.4 min/day) and vigorous-intensity PA (1.2 min/day versus 11.8 min/day). Additionally, when assessing participants adherence to international recommendations (i.e. accumulation of 150 min/week of MVPA in bouts of ≥ 10 minutes), 5% of candidates for bariatric surgery met the recommendations when compared to 40% of controls, and more candidates for bariatric surgery failed to accumulate MVPA in bouts of ≥ 10 minutes when compared to controls (68% versus 13%). Compared with studies that have measured PA in candidates for bariatric surgery, fewer studies have investigated time spent in SB (22, 23, 536). The four studies that have investigated daily time spent in SB among candidates for bariatric surgery used the SAB and reported that they spent around 80% of their waking hours in SB (22, 23, 536). Although no studies have directly compared SB measured using objective methods between candidates for bariatric surgery and normal-weight controls, when comparing data from previous studies of candidates for bariatric surgery (22, 23, 536) to data from a population-based study (41), candidates for bariatric surgery appear to spend more of their waking hours in SB than the general population (80% versus 56%).

Regarding PA and SB levels following bariatric surgery, studies demonstrate a similar pattern of low level of PA and prolonged time spent in SB. This is despite the significant weight loss achieved with bariatric surgery (25, 26, 28, 29). Chapman et al (25) performed the first study to investigate patterns of PA and SB, using the SAM and the SAB, in people ≤ 18 months following restrictive bariatric surgery. Participants averaged 9,611 steps/day, and spent little of their waking hours in MVPA (5%) and most of their waking hours in SB (71%). Furthermore, their findings showed that MVPA was mostly accumulated in short bouts of ≤ 10 minutes, and SB was mostly accumulated in prolonged uninterrupted bouts of ≥ 30 minutes (25). A recent study investigated PA and SB levels, using the ActivPAL accelerometer, on average 9 years following RYGB (29). Their findings showed participants performed an average of 6,375 steps/day, with 37% of participants classified as sedentary (i.e. < 5,000 steps/day) and only 11% classified as active (i.e. ≥ 10,000 steps/day). Also, participants spent 88% of their waking hours in SB. Earlier research has reported that people over 2 years following RYGB were less active than non-obese controls (26, 28). When data from studies of bariatric surgery are compared to data from population-based studies, people who have undergone bariatric surgery appear to spend more time in SB than the general population (39, 537).

Few studies have investigated pre- to post-surgery changes in objective measures of PA, and fewer have measured changes in SB (4-9). The first study to investigate post-surgery changes in PA used the RT3 accelerometer and found no changes in total time spent in MVPA and MVPA accumulated in bouts of ≥ 10 minutes at 6 months post-surgery in a mixed sample of 20 participants (i.e. 13 LAGB and 7 RYGB) (5). Similarly, two studies that investigated changes in PA and SB levels using the Actigraph accelerometer found no significant changes in time spent in MVPA, MVPA accumulated in bouts of ≥ 10 minutes, or in time spent in SB in a sample of 56 women at 9 months following RYGB (8) and no changes in time spent in MVPA in a sample of 43 women at 9 months following RYGB (9). In contrast, King et al (6) investigated changes in measures of PA, using the SAM, in a sample of 310 participants (i.e. 214 RYGB, 67 LAGB, 29 others) and found, at 12 months following surgery, significant increases in median daily step count (7,563 vs 8,788 steps/day), minutes during which walking was measured (309 vs 340 min/day), and minutes during which high-cadence walking (step count > 80 steps/minute) was measured (72 vs 112 min/week). Similarly, King et al (7) investigated changes in both PA and SB, using the SAM, in a large sample of 473 participants who underwent different types of bariatric surgery (i.e. 329 RYGB, 108 LAGB, 26 LSG, 10 others) and found that were small reductions in SB and increases in PA during the first 12 months post-surgery that were maintained up to 3 years. At 12 months, there was a significant decrease of 28 min/day in the sedentary time (from 573 min/day to 545 min/day), and a significant increase of 29 min/week in MVPA (from 77 min/week to 106 min/week) or 17 min/week in MVPA bouts of at least 10 minutes (from 7 min/week to 24 min/week). The only study that investigated changes in objective measures of PA in people who underwent exclusively restrictive bariatric surgery, using a pedometer, also found improvements in PA measures following LAGB (4). At 12 months, valid pedometer data were only available for 37% of participants (n = 48) and a significant increase of 2,655 steps/day was found (from 6061 steps/day to 8716 steps/day). The contrasting findings regarding improvements in PA measures reported by different studies could be explained by the difference in the motion sensors used and varied follow-up times. The aforementioned studies may also have been underpowered due to small sample sizes, and have important limitations regarding the assessment methods used that might explain different findings, including low adherence to the motion sensor used (4), suboptimal placement of the motion sensor (e.g. waist or hip) (5, 8), and possible misclassification of SB and MVPA due to the use of indirect measures (i.e. estimated from step counts) (6, 7). Furthermore, the majority of participants from these studies underwent RYGB, which is a mixed bariatric procedure and results in much greater weight loss when compared to LAGB (3). Also, although the weight loss following RYGB appears to be similar to that achieved with LSG, when compared to restrictive bariatric procedures, RYGB typically results in longer hospital stay, higher rates of post-surgery complications and nutritional deficiencies that may influence people's participation in PA (3, 55, 56). Therefore, findings from these studies may have limited generalisability to people who undergo restrictive bariatric surgery. Table 2.1 summarises the main characteristics and findings of studies that investigated pre- to post-bariatric surgery changes in objective measures of PA and SB.

Table 2.1 Studies that investigated pre- to post-bariatric surgery changes in objective measures of physical activity and sedentary behaviour

Study	Device	Measures of PA and/or SB
Colles et al.(4) n = 48 (LAGB)	Sportline 330 pedometer	*Steps per day - Mean (SD)* Pre-surgery: 6,061 (2,740) 12m Post-surgery: 8,716 (5,348)*
Bond et al. (5) n = 20 LAGB = 13 RYGB = 7	RT3 accelerometer	*MVPA min/week in bouts ≥1min - Mean (SD)* Pre-surgery: 186 (169) 6m Post-surgery: 151 (118) *MVPA min/week in bouts ≥10min - Mean (SD)* Pre-surgery: 41 (109) 6m Post-surgery: 40 (71)
King et al. (6) n = 310 RYGB = 214 LAGB = 67 Others = 29	StepWatch 3 activity monitor	*Steps per day - Median [IQR]* Pre-surgery: 7,563 [5,570-9,575] 12m Post-surgery: 8,788 [6,655-11,149]* *Active min/day (>0 steps/min) - Median [IQR]* Pre-surgery: 309 [245-380] 12m Post-surgery: 340 [276-413]* *High-cadence min/week (>80 steps/min) - Median [IQR]* Pre-surgery: 72 [34-130] 12m Post-surgery: 112 [50-185]* *High-cadence min/week in bouts ≥10min - Median [IQR]* Pre-surgery: 0 [0-26] 12m Post-surgery: 23 [0-680]*
King et al. (7) n = 473 RYGB = 329 LAGB = 108 LSG = 26 Others = 10	StepWatch 3 activity monitor	*Steps per day - Mean (95% CI)* Pre-surgery: 7,688 (7,401-7,974) 12m Post-surgery: 8,959 (8,623-9,294)* 24m Post-surgery: 9,214 (8,848-9,581)* 36m Post-surgery: 8,935 (8,565-9,306)* *MVPA min/week - Mean (95% CI)* Pre-surgery: 77 (71-84) 12m Post-surgery: 106 (98-116)* 24m Post-surgery: 113 (100-123)* 36m Post-surgery: 99 (88-110)* *MVPA min/week in bouts ≥10min - Mean (95% CI)* Pre-surgery: 7 (5-10) 12m Post-surgery: 24 (18-29)* 24m Post-surgery: 25 (19-33)* 36m Post-surgery: 17 (13-24)*

continues next page

Study	Device	Measures of PA and/or SB
		SB min/day - Mean (95% CI) Pre-surgery: 573 (564-582) 12m Post-surgery: 545 (534-555)* 24m Post-surgery: 548 (538-559)* 36m Post-surgery: 547 (536-559)* *SB min/day in bouts ≥10min - Mean (95% CI)* Pre-surgery: 407 (396-418) 12m Post-surgery: 381 (369-392)* 24m Post-surgery: 388 (376-400)* 36m Post-surgery: 386 (373-400)* *SB min/day in bouts ≥30min - Mean (95% CI)* Pre-surgery: 218 (208-227) 12m Post-surgery: 193 (184-202)* 24m Post-surgery: 201 (191-211)* 36m Post-surgery: 199 (187-210)*
Berglind et al. (8) n = 56 (RYGB)	Actigraph accelerometer	*MVPA min/day - Mean (SD)* Pre-surgery: 31 (18) 9m Post-surgery: 32 (24) *MVPA min/week bouts ≥10min - Mean (SD)* Pre-surgery: 26 (26) 9m Post-surgery: 30 (31) *LIPA min/day - Mean (SD)* Pre-surgery: 441 (92) 9m Post-surgery: 441 (93) *SB min/day - Mean (SD)* Pre-surgery: 430 (142) 9m Post-surgery: 421 (129)
Berglind et al. (9) n = 43 (RYGB)	Actigraph accelerometer	*MVPA min/day - Mean (SD)* Pre-surgery: 31 (18) 9m Post-surgery: 31 (21) *MVPA min/week bouts ≥10min - Mean (SD)* Pre-surgery: 28 (26) 9m Post-surgery: 28 (29) *LIPA min/day - Mean (SD)* Pre-surgery: 438 (91) 9m Post-surgery: 437 (92) *SB min/day - Mean (SD)* Pre-surgery: 442 (142) 9m Post-surgery: 434 (124)

Abbreviations: CI: confidence interval; IQR: interquartile range; LAGB: laparoscopic adjustable gastric banding; LSG: laparoscopic sleeve gastrectomy; MVPA: moderate to vigorous intensity physical activity; LIPA: light intensity physical activity; PA: physical activity;

RYGB: *Roux-en-Y* gastric bypass; SB: sedentary behaviour; SD: standard deviation. *p<0.05 for pre- to post-surgery change.

The few studies that have investigated changes in PA and SB from pre- to post-surgery have suggested little or no change in total time and bout-related time spent MVPA and SB. Additionally, findings indicated that a large portion of people failed to achieve the international PA recommendations post-surgery and, when compared to the general population, spent more of their waking hours in SB. To date, there has been no investigation of pre- to post-surgery changes in PA and SB following LAGB and LSG, measured using accelerometers or portable metabolic monitors. Further, most studies in this population have focused on measures of MVPA and daily step count, with little attention given to the way in which people spend most of waking hours (i.e. SB and light intensity PA). Thus, studies using accelerometers and portable metabolic monitors, which provide detailed information regarding the pattern in which PA, at any intensity, and SB are accumulated are needed (538). More detailed information on the influence of restrictive bariatric surgery on PA and SB is relevant since these procedures have been increasingly performed in Australia (308), and people who undergo bariatric surgery are still at risk of health conditions related to participation in low levels of PA and increased time in SB (e.g. increased risk of DM2, CVD and mortality), irrespective of the substantial weight loss achieved post-surgery.

2.5.1 Summary

Despite the significant and sustained weight loss and improvement and/or resolution of comorbid conditions achieved following bariatric surgery, there is data to suggest that the pattern of participation in little PA and increased time spent in SB found among candidates for bariatric surgery remains mostly unchanged post-surgery (5, 7, 8). Following surgery, if people do not change their PA and SB, they remain at risk of the detrimental effects of participation in little PA and increased time spent in SB, regardless of the large and significant weight loss achieved. Of note, data from studies that investigated pre- to post-surgery changes in PA and SB suggest that people who undergo bariatric surgery might need additional interventions to improve their participation in PA and decrease time spent in SB, given that the post-surgery weight loss and improvement and/or resolution of obesity-related comorbid conditions alone seem to be insufficient to promote changes in PA and SB. For this reason, there has been an increased interest in the possible additional effects of behavioural interventions that include a PA component on post-surgery outcomes among people who undergo bariatric surgery (35). Findings from a recent RCT indicated that, when compared to standard pre-surgery care, a comprehensive behavioural intervention, which addressed factors relevant to PA (e.g. barriers and facilitators to PA), resulted in significant short-term increases in time spent in PA prior to surgery (34). Although there are some data to suggest that a behavioural intervention can be effective at increasing people's participation in PA in the short-term, the long-term and post-surgery sustainability of any increase in PA following the completion of such an intervention has not yet been investigated. Further, there has been no investigation of the effects of a behavioural intervention aimed at optimising participation in PA in people following bariatric surgery on changes in PA and other relevant health outcomes, such as reduced cardiometabolic risk factors and weight maintenance.

2.6 Perceived barriers and facilitators to physical activity prior to and following bariatric surgery

This section provides a summary of the evidence for barriers and facilitators to PA in adults, with focus on the bariatric surgery population. These considerations are relevant to the research questions addressed in the second study undertaken in this programme of research. Despite the vast knowledge of the health benefits associated with regular participation in PA, population-based data from 122 countries have shown that a third of adults do not meet the recommended amount of PA to improve and/or maintain health (389, 390). The most recent survey that investigated levels of PA in Western Australia reported that in 2009, 40% of the adult population was considered either not active (i.e. reported no participation in PA) or insufficiently active (i.e. reported participation in PA that did not meet the national recommendations) (192). Public health initiatives (e.g. http://www.findthirtyeveryday.com.au) that aimed to inform Australian adults about PA guidelines, and suggest strategies to increase participation in PA have resulted in little or no change in reported PA levels (192, 226). A number of theories have helped clinicians to understand the complex mechanisms of PA behaviour change (e.g. Self-determination Theory, Theory of Planned Behaviour, Social Cognitive Theory), and there is evidence to show that theory-based interventions are an effective way of changing PA behaviour (11, 539, 540). The understanding of the mechanisms of PA behaviour change requires an understanding of the different factors related to people’s participation in PA (10, 11).

Among the multiple factors related to participation in PA, studies of the general population have mostly investigated people’s perceptions of barriers to PA, which are factors that would make it difficult or prevent them from engaging in PA, and facilitators to PA, which are factors that would make it easier for people to engage in PA. Earlier research has reported several barriers to PA in the general adult population, typically assessed using surveys or questionnaires (197-208, 210). Whether these barriers are real (i.e. a factor that truly influences participation in PA) or perceived (i.e. a factor that people believe to influence participation in PA), they may limit or prevent regular participation in PA (199). The most frequently reported barriers to PA among adults in the general population include lack of time, lack of motivation, work and family commitments, social issues (e.g. lack of support or lack of company to engage in PA), pain, and poor health (197-207). When compared to studies investigating barriers to PA, fewer studies have investigated facilitators to PA among adults in the general population (208-210). The most recent study used qualitative focus groups to explore the facilitators to PA among working parents and showed that being physically active with children, being a role model for children, prioritising PA, and social support were considered as facilitators to PA (210). There is evidence to show that factors related to participation in PA may be specific to population sub-groups (211-213). For example, people with chronic health conditions present with disease-related beliefs and barriers such as fatigue and decreased mobility, pain, presence of comorbid conditions, and fear of injury that influence their participation in PA (211-213).

Different studies have compared the barriers to PA, mostly using questionnaires, between adults within the normal-weight range and those considered obese (217, 224, 541-544).Their findings showed that when compared to those within the normal-weight range, adults who were obese reported a greater number of barriers to PA (217, 224, 541-544). Leone et al (224) used an online survey to compare participants’ agreement to different barriers to exercise between obese and non-obese women. When compared to non-obese women, those who were obese reported greater agreement to 5 out of 6 barriers, including ‘my current weight makes it difficult for me to exercise’ (47% versus 7%), ‘I do not have anyone to exercise with’ (49% versus 41%), ‘I usually only exercise if I am trying to lose weight’ (42% versus 18%), ‘I do not have the energy to exercise’ (58% versus 42%), and ‘I am uncomfortable with how I look while exercising or while wearing exercise clothing' (44% versus 26%). Napolitano et al (217) investigated barriers to PA among 280 women, using the Expected Outcomes and Barriers for Habitual Physical Activity Scale, and found that those who were obese reported significantly greater barriers to PA when compared to those within normal-weight and overweight. Specifically, the barriers to PA that were more likely to be elevated for women who were obese were feeling too overweight, feeling self-conscious when exercising, minor aches and pains, and lack of self-discipline or willpower. There are no studies comparing facilitators to PA between people who were normal-weight and obese in the general population.

Several studies that investigated barriers to PA exclusively among obese populations have consistently reported that in addition to the barriers commonly found in the general population (e.g. lack of time and lack of motivation), people who are obese often report obesity-related barriers to PA, such as feeling overweight or obese, self-consciousness about their body size, decreased fitness, and perceived laziness or lack of self-discipline, (214-216, 218, 219, 545, 546). For instance, a study of women who were overweight and obese involved in a weight loss program found that the main barriers to PA, assessed using a questionnaire, among inactive participants were lack of time, perceived laziness, health concerns, family commitments, illness or injury, environmental issues (i.e. weather, location, costs), lack of company, lack of confidence, and tiredness (219). Cannioto et al (546) used an online survey to assess the barriers to PA in a group of 30 overweight and obese working women and reported similar findings. Participants reported motivational factors (e.g. laziness, lack of energy) and lack of time to be the main barriers to PA, followed by home and family obligations, psychological limitations (e.g. poor body image, embarrassment about weight gain, insecurity), factors related to convenience and access to facilities, and lack of social support. Large cross-sectional studies have shown that the perception of being overweight also acts as a barrier to PA among Australian adults who are obese, and it is associated with lower odds of achieving the recommended levels of PA (214, 215). The few studies that investigated facilitators to PA in people who are obese highlighted that weight loss was the most frequently reported facilitator in this population (219, 220). One of these studies used a questionnaire to assess self-reported facilitators to PA of inactive women who were overweight and obese and participated in a weight loss program, and found that weight loss and better fitness were the factors most frequently described (219). Igelstrom et al (220) assessed facilitators to PA of people who were obese with OSA, using qualitative semi-structured interviews, and found that participants perceived that PA would be facilitated if they lost weight, made PA a priority, and received social support.

Despite some data on barriers and facilitators to PA in the general population and people who are obese, these might not be applicable to those who undergo bariatric surgery. This is because bariatric surgery is usually considered after a history of repeated unsuccessful attempts to lose weight using conservative methods (e.g. diet combined with increased PA), which could result in a different perception of factors related to participation in PA among people who undergo bariatric surgery, when compared to the general obese population (221, 547). Previous studies have shown that the experience of repeated unsuccessful attempts to lose weight among people who underwent bariatric surgery resulted in feelings of hopelessness and desperation regarding their body weight, perceived lack of control over PA and eating behaviours, as well as low confidence and self-esteem (221, 547). Since previous studies have shown that, when compared to the general population and people within the normal-weight range, people who undergo bariatric surgery spend less time engaging in PA and more time in SB (21, 25), it is reasonable to believe that this population experiences specific and salient obesity-related factors that influence their participation in PA.

An RCT that compared standard pre-surgery care to a pre-surgery comprehensive theory-based behavioural intervention produced significant short-term improvements in objective measures of MVPA prior to bariatric surgery (34). Specifically, the intervention consisted of counselling sessions that included problem solving for barriers to PA, goal setting regarding purposeful walking and the use of behavioural and cognitive strategies aimed at increasing self-efficacy and motivation to PA (34). Despite some data to support that an intervention that targets factors related to participation in PA, such as barriers to PA, can produce significant increases in PA pre-surgery, more data are needed on the perceived barriers and facilitators to PA in order to guide interventions to increase participation in PA in people who undergo bariatric surgery. Few cross-sectional studies have reported on barriers to PA pre- or post-surgery (222, 223, 225, 548).Two studies have investigated barriers to PA among candidates for bariatric surgery (223, 548). One of these studies retrospectively assessed pre-surgery barriers to PA among 30 people who underwent bariatric surgery, using a questionnaire that included environmental, social, behavioural, and physical barriers (548). The majority (> 93%) of participants reported behavioural and physical barriers to PA, with the most commonly reported barriers being ‘concern about appearance’, ‘concern about clothes during PA’, ‘physical tiredness’, and ‘physical limitations’. Social barriers, mainly ‘extensive work hours’ and ‘lack of company’ were reported by a large portion (> 80%) of participants, and ‘lack of equipment’ was the most frequent of the environmental barriers reported by 57% of participants (548). Wiklund et al (223) used qualitative semi-structured interviews to explore how 18 obese adults scheduled to undergo RYGB experienced PA, including factors that prevented their participation in PA. Participants reported being embarrassed to be seen wearing exercise clothing, joint pain as a result of being obese, difficulties to manage a large body, difficulties to find an appropriate intensity of PA that could be tolerated and to adjust PA to the level of others.

The few cross-sectional studies that have investigated barriers to PA post-surgery have mostly used questionnaires or surveys (222, 225, 548). The study with the largest sample (n = 366) investigated post-surgery barriers to PA using an online survey and divided barriers into internal (i.e. motivational and physical barriers) and external barriers (i.e. time, weather, resources, support, holidays) (222). The most frequently reported internal motivational barriers were ‘difficulty maintaining consistency of exercise behaviours’, ‘difficulty making exercise a priority’, ‘general motivational difficulties’, and ‘lack of enjoyment’. The most frequently reported internal physical barriers were ‘general physical limitations’ (e.g. pain and chronic illness) and ‘post-surgery issues’ (e.g. lack of stamina and diet-related problems), while the most frequently reported external barriers were ‘lack of time’ and ‘weather’. The only study using qualitative semi-structured interviews aimed to explore the experiences of PA of 24 people at 12 months following RYGB (225). Participants reported experiencing physical limitations of being overweight and post-surgery issues (e.g. excess skin and diarrhoea), lack of motivation and boredom related to exercising on their own, as well as embarrassment related to exposing themselves in front of other while engaging in PA.

Although no studies have specifically investigated facilitators to PA in people who underwent bariatric surgery, a cross-sectional qualitative study that aimed to explore the PA experiences of people scheduled to undergo RYGB indicated that participants believed losing weight would facilitate their participation in PA (223). A qualitative study that also explored the PA experiences of people at 12 months following RYGB, reported that participants believed the weight loss achieved post-surgery facilitated engagement in PA due to improvements in physical limitations related to obesity (225).

Studies of people who underwent bariatric surgery have investigated factors that may be related to, or have been reported as, barriers to PA, mostly among those who underwent RYGB. Their findings suggest that, prior to surgery, this population presents with persistent musculoskeletal pain and impaired walking capacity and physical function (85, 423, 549-552). Further, their findings report significant improvements in objective measures (e.g. scales, walking and functional tests) of musculoskeletal pain, walking capacity and physical function following surgery. A recent study has investigated changes in self-reported pain and physical function, measured by scales on the SF-36, and physical function measured by the 400-metre walk time, in a sample of 2,221 people who underwent bariatric surgery (70% RYGB, 25% LAGB, 5% other) (85). When compared to pre-surgery measures, clinically meaningful improvements were reported at 1 year post-surgery in 58% (95% CI, 55 to 60%) of participants for bodily pain, 77% (95% CI, 75 to 79%) for physical function, and 60% (95% CI, 56 to 63%) for walk time. Furthermore, more than 75% of participants with severe pre-surgery knee/hip pain or disability reported joint-specific improvements in knee pain (77%; 95% CI, 74 to 81%) and in hip function (79%; 95% CI, 75 to 83%). The findings have also shown that between 1 and 3 years post-surgery, while improvement rates for walk time, knee/hip pain and function did not change, the improvement rates for bodily pain and physical function measured by the SF-36 significantly decreased (85). Although significant improvement in such measures have been shown, studies indicate that people continue to report the presence of musculoskeletal pain and present with impaired physical function following bariatric surgery (549, 552). Furthermore, it is not clear if these improvements in pain and physical function are related to change in people’s participation in PA (85, 419, 423, 552).

Most studies that have investigated factors related to participation in PA in different populations have relied on quantitative methods, such as structured questionnaires or scales, which despite being useful and easy to apply, are likely to restrict the choice of participants’ response (206, 214, 215, 217, 222). In contrast to quantitative methods, the use of qualitative methods, such as interviews or focus groups does not limit people’s responses to pre-specified items and allows for a rich, detailed exploration of reasons why people participate in PA (e.g. barriers, facilitators, motivators to PA) (210, 223-225). Additionally, the use of a qualitative exploration provides an in-depth insight into people's perceptions and experiences within the social context of a particular population (202, 210, 223-225). Rich, in-depth and detailed information regarding pre- and post-surgery beliefs about PA, and perceptions of factors that influence PA, such as barriers, facilitators and motivators to PA, as well as the way in which these change could offer insight into the reasons for the little participation in PA among people who undergo bariatric surgery. This information is important to inform clinicians and develop interventions aimed at optimising participation in PA both pre and post-surgery (74, 75, 226, 227).

2.6.1 Summary

There is some evidence to show the presence of obesity-related barriers to PA, in addition to those commonly found in the general population, both prior to and following bariatric surgery. Findings from previous studies have reported weight loss as the main perceived facilitator to PA identified both pre- and post-surgery. However, there is a lack of studies that provide in-depth information regarding factors the bariatric surgery population believe to be related to participation in PA, particularly among people who undergo restrictive bariatric surgery. This paucity of in-depth knowledge is because previous studies relied mostly on questionnaire or survey data obtained cross-sectionally, where the types of barriers and facilitators to PA were pre-determined by the researchers. The use of qualitative methods allows for a rich in-depth exploration of people's perceptions and experiences without restricting findings to pre-specified responses. Furthermore, no studies have investigated changes in the perceptions of factors related to participation in PA among those who underwent bariatric surgery. A longitudinal qualitative exploration aimed at understanding people's perceptions of how factors related to PA change post-surgery could inform the development of interventions that provide the best chance for success at optimising participation in PA and health benefits both pre- and post-bariatric surgery (34, 38, 75, 222, 227, 553). The few studies of bariatric surgery that used qualitative methods were of people who underwent RYGB, who may have different experiences of factors related to participation in PA when compared to those who undergo restrictive procedures due to different post-surgery recovery and outcomes. Longitudinal qualitative explorations of factors related to participation in PA, such as perceived barriers, facilitators and motivators to PA, as well as the way in which surgery influences such factors are warranted. Such explorations are needed to guide behavioural interventions aimed at optimising PA in this population, given the substantial increase in the amount of restrictive bariatric surgery being performed (1), particularly in Western countries, and the beneficial effects of increasing participation in PA in this population, independent of weight loss.

CHAPTER 3 METHODS

Overview

This chapter presents the methods used in the two studies undertaken as part of this programme of research. Section 3.1 describes the methods used for Study 1. Section 3.2 describes the methods used for Study 2. For both studies, the study design, inclusion and exclusion criteria, recruitment process, assessment protocol, and data analyses are described. For Study 1, Section 3.1 also describes the outcome measures used.

3.1 Study 1

3.1.1 Study design

3.1.1.1 Overview

The study was longitudinal and observational in design. Data collection was undertaken between June 2013 and July 2015. Adults scheduled to undergo restrictive bariatric surgery were recruited from two private bariatric clinics in Perth, Western Australia. Prior to and over the first 12 months following surgery measures were collected of physical activity (PA) and sedentary behaviour (SB), cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, body composition and bone mineral density (BMD), weight-related measures, obesity-related comorbid conditions, health-related quality of life (HRQoL), obesity-related quality of life and weight-related symptoms, and symptoms of depression, anxiety and stress. The results from this study are presented and discussed in Chapter 4 (Study 1 - Results and discussion).

3.1.1.2 Approval from human research ethics committee

The study was approved by the Human Research Ethics Committee at Curtin University (approval number HR 08/2013).

3.1.1.3 Participants

3.1.1.3.1 <u>Inclusion criteria</u>

Individuals were eligible to participate in the study if they were aged over 18 years, with body mass index (BMI) > 30 kg/m^2 and scheduled to undergo primary laparoscopic adjustable gastric banding (LAGB) or laparoscopic sleeve gastrectomy (LSG).

3.1.1.3.2 Exclusion criteria

Exclusion criteria comprised; (i) pregnancy or planning pregnancy within 12 months, (ii) presence of a permanent health condition such as a neurological, cardiovascular or orthopaedic disease that could compromise the performance of daily PA, (iii) body weight over 160 kg (due to weight limit of equipment used for assessments), and (iv) cognitive impairments or language barriers which could interfere with participation in the assessments.

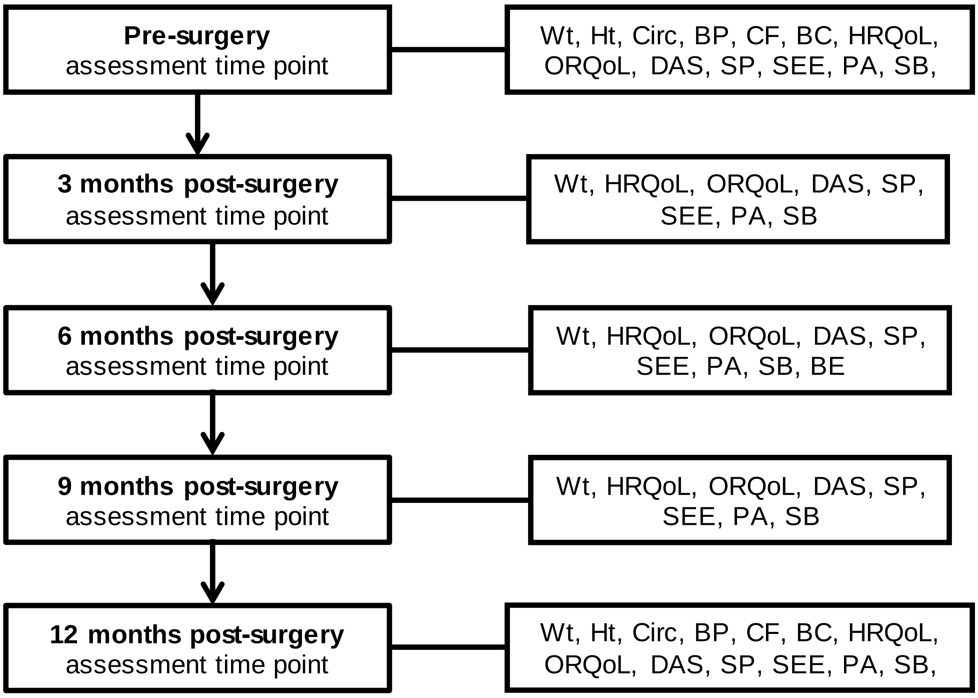
3.1.2 Recruitment

Participants were recruited between April 2013 and June 2014. 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 who granted permission to be contacted were approached to participate in the study. All participants signed a written informed consent form prior to data collection.

3.1.3 Assessment protocol

Data collection comprised one assessment time point within the month prior to surgery and four assessment time points following surgery. The post-surgery assessment time points took place 3, 6, 9 and 12 months following the date of surgery. Figure 3.1 summarises the assessment protocol. At the pre-surgery and 12 months post-surgery assessment time points, measurements were obtained of weight, height, waist circumference, systolic and diastolic blood pressure, cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, body composition and BMD, HRQoL, obesity-related quality of life and weight-related symptoms, and symptoms of depression, anxiety and stress. Participants were also fitted with two activity monitors to collect measures of PA and SB. The presence of any medically diagnosed obesity-related comorbid condition (i.e. diabetes mellitus type 2 [DM2], dyslipidaemia, hypertension, and obstructive sleep apnoea), medication use and the use of continuous positive airway pressure treatment was documented. Participants also had a venous blood sample collected to measure fasting glucose, total fasting cholesterol, high-density and low-density lipoprotein cholesterol, and fasting triglycerides to confirm any medical diagnosis of obesity-related metabolic comorbid conditions. Participants with DM2 had glycosylated haemoglobin measured.

At the 3, 6 and 9 months post-surgery assessment time points, measures were collected of weight, PA and SB, self-efficacy to exercise, sleep quality, daytime sleepiness, HRQoL, obesity-related quality of life and weight-related symptoms, and symptoms of depression, anxiety and stress. The pre-surgery and 12 months post-surgery assessment time points lasted 8 days (7 days of PA monitoring and 1 day to collect all the other measures), and the 3, 6 and 9 months post-surgery assessment time points lasted for 7 days and were done remotely (via post and telephone contact).



BC: body composition; BE: Blood exams; BP: systolic and diastolic blood pressure; CF: cardiovascular fitness; Circ: waist and hip circumferences; DAS: symptoms of depression, anxiety and stress; HRQoL: health-related quality of life; Ht: height; ORQoL: obesity-related quality of life; PA: physical activity; SB: sedentary behaviour; SP: sleep problems; SEE: self-efficacy to exercise; Wt: weight;

Figure 3.1. Assessment protocol.

3.1.4 Measures

3.1.4.1 Descriptive measures

Pre-surgery, descriptive measures were collected, including type of bariatric surgery to be performed, gender and height (measured to the nearest 1 cm on a stadiometer, with the participants dressed in light clothing without shoes). During the hospitalisation period immediately following surgery, details were documented regarding the hospital length of stay and development of any peri-operative or early post-operative complications.

3.1.4.2 Primary outcome measures

3.1.4.2.1 Physical activity and sedentary behaviour

Participants were instructed to wear two activity monitors for 7 consecutive days, 24 hours per day, in order to minimise missing data due to non-wear periods (e.g. participants forgetting to put monitors back on as soon as they wake up) (20, 40, 554). They were asked to remove the activity monitors only when performing water activities (e.g. bathing, swimming).

SenseWear Armband™

The SenseWear Armband™ (SAB; Bodymedia Inc., Pittsburgh, PA, United States of America [USA]) is a small, light-weight portable metabolic monitor worn on the upper posterior region of the left arm (over the triceps brachii muscle). The device estimates energy expenditure using proprietary software (SenseWear Professional 7.0, Bodymedia Inc., Pittsburgh, PA, USA) which integrates non-invasive physiological measures such as skin temperature and galvanic response together with movement measures obtained from a tri-axial accelerometer. Data are expressed as metabolic equivalents (METs). Based on previous research, time spent in SB and PA at different intensities was estimated according to different thresholds of energy expenditure, reported as METs. Each minute of waking hours was grouped into the following categories; SB (i.e. < 1.5 METs), light intensity PA (i.e. 1.5 to < 3 METs), and moderate to vigorous intensity PA (≥ 3 METs) (382, 386, 387). The device has been shown to produce valid and reliable measures of energy expenditure in healthy normal- and overweight adults (420-422). The SAB has also been used in studies of people who are obese and those who underwent bariatric surgery (34, 40, 423).

StepWatch 3 Activity Monitor™

The StepWatch 3 Activity Monitor™ (SAM; Cyma Corp., Seattle, WA, USA) is a small microprocessor-driven pedometer that is worn just above the lateral malleolus on the right leg and attached with a strap. The SAM detects and counts steps every minute, for different gait styles. The output is expressed as the number of steps per day taken by the right leg and therefore the step count is multiplied by two in order to obtain the total number of steps taken. This device has been shown to provide a valid and reliable measure of number of steps in lean and obese healthy adults (416). The device has been used in research involving people who underwent bariatric surgery (6, 7, 554).

3.1.4.3 Secondary outcome measures (outcomes relevant to physical activity)

3.1.4.3.1 Cardiovascular fitness

Cardiovascular fitness was assessed with the Physical Working Capacity 170 (PWC-170) test, a submaximal exercise test designed to estimate the work capacity of a participant at a heart rate of 170 beats per minute (555, 556). Participants were required to rest (sitting on a chair) for at least 10 minutes prior to the test. Prior to and following the test, measurements were made of heart rate and blood pressure using a manual sphygmomanometer (Spirit Medical Co., Ltd, Taipei, Taiwan, China). Heart rate and arterial oxygen saturation (SpO_2) were continuously monitored during the test using a polar monitor (Polar FT1, Polar Electro Oy, Kempele, Oulu, Finland), and a pulse oximeter and finger sensor (GE Ohmeda TuffSat, GE, Helsinki, Finland), respectively.

The test was conducted on an electronically braked cycle ergometer (Lode Corival, Groningen, Netherlands) and comprised three stages. Each stage had a maximum duration of 6 minutes and was performed at increasing work rates (Watts [W]) with the aim of reaching target heart rates of 120, 135, and 150 beats per minute. Participants cycled at 60 revolutions per minute during the entire test. The participants performed a warm up period, cycling against a 10 W workload for 1 minute followed by the initial workload, set at 25 W for all participants. To arrive at the target heart rates, work rates were modified each minute for each participant. The amount by which work rates were modified to reach the target heart rates was individualised. On completion of the final stage, participants completed a 1 minute cool down. 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 beats per minute (557).

Rather than a maximal exercise test, which would have allowed the measurement of the peak rate of oxygen uptake, a submaximal cycle exercise test was chosen for this study. There were two reasons for this decision. First, undertaking a maximal exercise test would require the participant to exercise to exhaustion, and this may not have been possible in this population due to the mechanical difficulties resulting from a large body size, together with joint pain and exacerbation of obesity-related comorbid conditions (e.g. hypertension) (347). Second, given the risk associated with undertaking a maximal exercise test in this population, the test would necessitate the use of a 12-lead electrocardiogram and supervision by a medical practitioner, which was not possible with the funding available to conduct this study. Submaximal exercise tests have been widely used to assess cardiovascular fitness, including in obese populations (347, 349, 555, 556).

3.1.4.3.2 <u>Self-efficacy to exercise</u>

Self-efficacy to exercise was assessed using the Exercise Self-Efficacy Scale (ESES) described by Bandura (558). The ESES presents 18 different scenarios and asks the respondent to rate the degree of confidence in their ability to exercise in each scenario. The degree of confidence is measured with a scale that ranges from 0 (cannot do this activity at all) to 100 (highly certain can do this activity) (558). The ESES has been used in studies of people who are overweight and obese with chronic health conditions, such as obstructive sleep apnoea (220), and cardiovascular disease (559).

3.1.4.3.3 <u>Sleep quality</u>

The Pittsburgh Sleep Quality Index (PSQI) is a self-reported questionnaire that assesses both sleep quality and disturbance that might affect sleep quality. It comprises 19 items and covers the components of sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medications, and daytime dysfunction (362). A total sleep quality score is calculated, that ranges from zero to 21, with scores > 5 associated with poor sleep quality. Good psychometric properties of the PSQI have been confirmed in the general population and people with chronic health conditions (e.g. breast cancer, renal transplants) (560), and it has been used in studies of people who are obese and those who underwent bariatric surgery (96, 364).

3.1.4.3.4 Daytime sleepiness

The Epworth Sleepiness Scale (ESS) is a simple measure of daytime sleepiness that uses a 4-point Likert type scale to measure the chance of dozing in eight day-to-day situations (561, 562). The Likert type scale ranges from zero (would never doze) to three (high chance of dozing). A global score is calculated by the sum of all item scores, ranging from zero to 24, with a score ≥ 10 indicating excessive daytime sleepiness. The reliability and internal consistency of the ESS was shown in adults (365), and it has been used in studies investigating people who are obese (87) and those who underwent bariatric surgery (93, 258).

3.1.4.3.5 Body composition and bone mineral density

Body composition and BMD were assessed using whole-body dual energy x-ray absorptiometry (DXA) scanning (Lunar Prodigy, GE Healthcare, Diegem, Belgium). Measures were collected of fat mass (FM), percentage of FM, fat-free mass (FFM), percentage of FFM, and total, spine and pelvis BMD, as well as total body BMD T-scores using proprietary software (encore v15 SP1, GE Healthcare, Shanghai, China). For those participants who did not fit the scanning area of the DXA scanner, two half body measures were performed and results were derived from the sum of left and right body measures. The way in which DXA measures were made for each participant was the same at both the pre-surgery and 12-month post-surgery assessments. Changes in measures of body composition and BMD using DXA have been investigated following different types of bariatric surgery (105, 113, 117, 563).

3.1.4.4 Secondary outcome measures (outcomes used to confirm the previously established efficacy of restrictive bariatric procedures)

3.1.4.4.1 Weight-related measures

At the pre-surgery and 12 months post-surgery assessments, weight was measured to the nearest 0.1 kg on a calibrated scale, with the participants dressed in light clothing without shoes. At the 3, 6, and 9 months post-surgery assessment, participants were instructed to weigh themselves on a calibrated scale, dressed in light clothing without shoes, and report the weight measured. The participant's weight and height were used to calculate the BMI (i.e. weight in kilograms divided by the height in metres squared [kg/m^2]). Waist circumference was measured using a non-elastic tape measure, at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest (230).

3.1.4.4.2 Measures associated with obesity-related comorbid conditions

Venous blood samples were used to obtain measures of fasting glucose, glycosylated haemoglobin, total fasting cholesterol, high-density and low-density lipoprotein cholesterol, and fasting triglycerides, in order to confirm the medical diagnosis of any obesity-related metabolic comorbid conditions. Systolic and diastolic blood pressure was measured at rest using a calibrated manual sphygmomanometer (Spirit Medical Co., Ltd, Taipei, Taiwan, China). Improvement of a comorbid condition was confirmed by improvement in objective measures (e.g. blood samples) and by decrease in dosage and/or number of medications used. Resolution of a comorbid condition was confirmed by objective measures (e.g. blood samples) and cessation of medication use. Resolution of metabolic comorbid conditions was defined according to venous blood sample measures within the normal values without use of medication. The cut-offs used to define normal values for measures obtained by venous blood samples were: fasting glucose < 6.1 mmol/L, glycosylated haemoglobin < 7.8 mmol/L, total fasting cholesterol < 5.5 mmol/L, high-density lipoprotein cholesterol < 3.5 mmol/L, low-density lipoprotein cholesterol > 1.0 mmol/L for men and > 1.3 mmol/L for women, and fasting triglycerides < 2.0 mmol/L (319, 564). Resolution of hypertension was defined as measured systolic blood pressure < 140 mmHg and diastolic blood pressure < 90 mmHg without use of medication (564).

Given sleep disordered breathing, the most common type being obstructive sleep apnoea, is a prevalent obesity-related comorbid condition, it was objectively assessed at all assessment time points with a portable single-channel recording device, the ApneaLink™ (ResMed Ltd, Bella Vista, NSW, Australia), and participants were asked to use the device for a whole night of sleep. Participants that used a continuous positive airway pressure device during sleep were asked to not use the device during the assessment night with the ApneaLink™. The ApneaLink™ uses a pressure-transduced oronasal airflow sensor and pulse oximetry to detect events suggestive of apnoea during sleep, and appears to accurately detect apnoea and/or hypopnoea events in morbidly obese (361) and people with sleep-related complaints and comorbid conditions (565). The apnoea-hypopnoea index, which is the frequency of apnoea and hypopnoea events per hour of sleep, was measured. Apnoea-hypopnoea index values ≥ 15 events per hour, or ≥ 5 events per hour in addition to self-reported symptoms of sleep disturbance (e.g. daytime sleepiness, unrefreshing sleep, fatigue, waking up breath holding, gasping , or choking, snoring) are indicative of sleep disordered breathing (357). This device has been used in studies of obese populations (359, 360).

3.1.4.4.3 Health-related quality of life, obesity-related quality of life and weight-related symptoms

Health-related quality of life

The Medical Outcomes Study Short Form 12 General Health Survey version 2 (SF-12v2) is a multidimensional, 12-item instrument that assesses generic HRQoL (566, 567). The survey, adapted for use in Australia, comprises eight health domains and two component summary measures; the physical component summary (PCS) and the mental component summary (MCS). The PCS comprises four health domains: physical functioning, role-physical, bodily pain, and general health. Similarly, the MCS comprises four health domains: vitality, social functioning, role-emotional, and mental health. The answers for each domain and component summary are scored on a scale from zero to 100, with higher scores representing better HRQoL. Each component summary of the SF-12v2 is standardised to a population mean of 50.0 (standard deviation, 10.0) arbitrary units (566). A change of 3 to 5 points in the summary scores of the SF-12v2 has been reported as clinically meaningful (568, 569). For both people who are obese and those with normal weight, the SF-12v2 has been shown to be highly correlated with the SF-36 (i.e. r values between 0.73 and 0.89) (570, 571), which is a longer version of the survey that has been widely used in studies of bariatric surgery (138, 154, 163, 572).

Obesity-related quality of life and weight-related symptoms

The short version of the Impact of Weight on Quality of Life Questionnaire (IWQOL-Lite), adapted for use in Australia, was used to assess obesity-related quality of life. It consists of 31 items within five scales: physical function, self-esteem, sexual life, public distress and work (573). Each item has five answer options, from one (never true) to five (always true), and the total score for the instrument is obtained by converting the raw scores of each scale into scores that range from zero to 100, with higher scores indicating lower impact of weight, and therefore, higher quality of life. A total score of the IWQOL-Lite ≥ 87.1 indicates no impairment in quality of life, 79.5 to 87.0 indicates mild, 71.9 to 79.4 indicates moderate, and < 71.9 indicates severe impairment in quality of life (574). A change of 12 points in the total score of the IWQOL-Lite has been reported as clinically meaningful (574). The IWQOL-Lite has been shown to be valid, reliable and sensitive to change in obese populations seeking treatment or not (573, 575).

The Obesity and Weight-loss Quality-of-life Instrument (OWLQOL) and Weight-related Symptoms Measure (WRSM), adapted for use in Australia, were used to measure obesity-related quality of life and weight-related symptoms. The OWLQOL measures people's perception of life status related to weight, weight loss and treatment for weight loss, while the WRSM is focused on symptoms usually associated with obesity and obesity treatment (493). All 17 items on OWLQOL are answered with a 7-point Likert type scale ranging from zero (not at all) to six (a very great deal) and are used with equal weight to create a single score. The score ranges from zero to 100, where zero indicates the lowest and 100 the best quality of life. The 20 items on WRSM are answered with either yes or no response followed by a bothersomeness scale, identical to the OWLQOL scale. The total score ranges from zero to 120, with higher scores representing worse burden of symptoms. Both instruments yield valid and reliable measures amongst people who are overweight and obese (576).

3.1.4.4.4 Mental health

The version 1 of the Beck Depression Inventory (BDI) was used to assess the presence of symptoms of depression. It comprises 21 items, each with four possible responses (from zero to three) (577). The sum of the item scores is used, with higher scores indicating higher severity of symptoms. Cut-off points have been describe to classified the severity of symptoms, with scores < 10 indicating none to minimal, 10 to 18 indicating mild to moderate, 19 to 29 indicating moderate to severe, and 30 to 63 indicating severe symptoms of depression. The BDI has been considered to be valid (578), and has been commonly used to assess depressive symptoms amongst candidates for bariatric surgery (181, 185, 188, 190).

The Depression Anxiety Stress Scales (DASS-21) were used to assess symptoms of depression, anxiety and stress. It comprises 21 items, rated on a 4-point Likert type scale that ranges from zero (did not apply to me at all) to three (applied to me very much, or most of the time) (579). Items from each subscale (i.e. depression, anxiety and stress) are summed and a higher score indicates higher severity of symptoms in that domain. Table 3.1 presents the cut-offs, relative to the general population, for the severity of symptoms of depression, anxiety and stress according to the subscales scores of the DASS-21. This instrument has been shown to be valid and reliable in clinical populations of diagnosed mental health disorders and in the general population (580, 581), and has been used in studies of people who are obese (582, 583).

Table 3.1 Severity of symptoms of anxiety, depression and stress according to the subscales of the DASS-21

Severity of symptoms	Depression subscale score	Anxiety subscale score	Stress subscale score
None	0 - 4	0 - 3	0 - 7
Mild	5 - 6	4 - 5	8 - 9
Moderate	7 - 10	6 - 7	10 - 12
Severe	11 - 13	8 - 9	13 - 16
Extremely severe	≥ 14	≥ 10	≥ 17

3.1.5 Data analyses

3.1.5.1 Power calculation

The sample size for this study was limited by feasibility, not dictated by the number needed to detect a particular effect. According to the time frame available for recruitment and data collection, as well as the average amount of surgeries performed in the bariatric clinics from where participants were recruited, a sample size of 30 participants was considered feasible. Although all measures of PA and SB were considered to be primary outcomes, due to limited information available on objectively-measured PA and SB among people undergoing bariatric surgery at the time this study was designed, the primary endpoints on which power calculations were undertaken were daily step count and time spent in SB. When daily step count was considered, the calculations were based on the pre-surgery daily step count reported by King et al. (20) (mean, 7569 steps/day; SD, 3159 steps/day) and by Langenberg et al. (27) (mean, 7140 steps/day; SD, 3422 steps/day). It was anticipated that 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-surgery and follow-up measures of 0.5. When time spent in SB was considered, the calculations were based on the pre-surgery time spent in SB (reported as percentage of waking hours) reported by Bond et al. (22) (mean, 81%; SD, 10%) and by Unick et al. (23) (mean, 80%; SD, 17%). It was anticipated that a feasible sample size of 30 participants would give a power of .89 to detect a 7.5% change in time spent in SB at α=.05, assuming a conservative correlation between pre-surgery and follow-up measures of 0.5.

3.1.5.2 Physical activity and sedentary behaviour data management

3.1.5.2.1 <u>Separating overnight sleep and non-wear time from total wear time</u>

Measurement of overnight sleep was excluded from the data collected with the SAB, since SB is defined as activities that involve low energy expenditure (i.e. < 1.5 METs), and are performed during waking hours, in a sitting or reclining posture (45, 387). Data from the SAB were exported to Excel™ and run through custom made software (LabVIEW 8.6.1; National Instruments, Austin, TX, USA) to exclude overnight sleep time. Using the custom made software, the beginning of the day was defined using postural data from the SAB, as the first time a participant accumulated ≥ 20 consecutive minutes, after 5 am, in any posture other than supine (i.e. lying down in a completely horizontal posture). The end of the day was defined as the first time a participant laid down (supine) for ≥ 20 consecutive minutes after 8 pm. An average of all days that met these criteria was used for analysis. Although the criteria used to define the beginning and end of the day were arbitrary, they are consistent with earlier work which defined the start of the day as starting before 7 am (20, 554) and would seem reasonable in the sample which was comprised by adults employed in day time jobs.

3.1.5.2.2 <u>Defining minimal requirements for inclusion in analyses</u>

There is considerable variability in the criteria used to define the minimum wear time needed for activity monitor data to be included in data analyses. Specifically, earlier research which has reported measures of PA and SB in people prior to and following bariatric surgery, have defined minimum acceptable monitor wear time as varying between 3 and 4 days, with at least 6 to 10 hours of data per day (6, 23, 34). Although earlier research does not consistently include data from a weekend day, studies of overweight and obese populations have reported significant differences in PA and SB levels between weekend and week days (584, 585). Large epidemiological studies (n > 1,600) of adults living in the USA that have investigated time spent in PA and SB have suggested that a minimum of 4 days, each contributing ≥ 10 h of wear time, and the inclusion of at least 1 weekend day is needed to estimate habitual PA and SB (491, 586).

For this programme of research, participants' data obtained with the activity monitors were included in the analyses if they contributed a minimum of 4 valid days of data which included at least 1 weekend day. A valid day of data was defined as ≥ 12 hours/day of monitor wear time. When comparing data from previous studies of bariatric surgery (22, 23, 536) to data from a population-based study (41), people who undergo bariatric surgery appear to spend more of their waking hours in SB than the general population (80% versus 56%). Therefore, the activity monitor wear time requirement of at least 12 hours/day was adopted to optimise the likelihood of capturing representative SB data in this sample. An average of all days that met these criteria was used for analysis. Although it is possible that different criteria may have yielded different estimates of PA and SB, a recent study in a large sample of adults who are overweight and obese with DM2 demonstrated that differences in minimum wear time criteria appear to have little effect on the estimate of PA (587).

3.1.5.2.3 Exploring how physical activity and sedentary behaviour were accumulated

To investigate how PA and SB were accumulated using data collected via the SAB, a custom made exposure variation analysis software was used (LabVIEW 8.6.1; National Instruments, Austin, TX, USA) (25, 588). The exposure variation analysis grouped the data in terms of intensity, using METs, corresponding to sedentary behaviour (< 1.5 METs), light intensity PA (1.5 to < 3 METs), and moderate to vigorous intensity PA (≥ 3 METs). Additionally, for each intensity, the duration of activity was grouped according to 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. Given the bariatric population has been shown to engage in little PA and spend most of their time in SB, data that reflects sub-optimal patterns of accumulation of SB and PA (i.e. short bouts of MVPA and prolonged bouts of SB) is reported. Previous research in the general adult population (44, 53, 391) has reported that prolonged periods of SB (i.e. ≥ 30 minutes) are associated with more detrimental health effects, when compared to short periods of SB. Recent studies that have investigated the association between different durations of uninterrupted bouts of objectively-measured SB and cardiometabolic risk factors, in the general and obese populations, have suggested that the accumulation of SB in uninterrupted bouts ≥ 10 minutes is a more conservative threshold to identify prolonged periods of SB and should be considered when using objective measures of SB (392, 393). Based on these earlier studies, the accumulation of SB in uninterrupted bouts of both ≥ 10 minutes and ≥ 30 minutes was explored. Regarding the accumulation of MVPA, it is possible that accumulating time in MVPA in very short bouts (i.e. < 10 minutes) may be less beneficial than accumulating time in MVPA in longer bouts (i.e. ≥ 10 minutes) (50). Therefore, the sub-optimal pattern of accumulation of time in MVPA in uninterrupted bouts < 10 minutes was explored. Finally, data on patterns of accumulation of SB and MVPA that appear to be more optimal for health were also investigated. That is, the amount of time participants engaged in short bouts (< 10 minutes) of SB and uninterrupted bouts ≥ 10 minutes of MVPA was also reported.

3.1.5.3 Statistical analyses

Statistical analyses were performed using Stata Statistical Software 13.1 for Windows (StataCorp LP, College Station, TX, USA). The distribution of data was assessed by graphical (frequency histograms) and statistical methods (testing and comparing skewness and kurtosis of a ladder of power transformations of each variable). Change in normally distributed variables measured pre-surgery, and 3, 6, 9, and 12 months post-surgery was analysed using multilevel, mixed-effects linear regression models. Multilevel regression models have advantages over traditionally used repeated measures analysis of variance in these circumstances as they (i) allow the correlation of the within-subject repeated measures to be explicitly accounted for, (ii) allow flexible modelling of time, and (iii) allow use of all cases including those with missing data at one or more time points, which allows for unbiased estimates for time-points with missing data providing data is at least missing at random (589). For these multilevel models, a variety of correlation structures were estimated and compared using maximum likelihood-based model-selection statistics, namely Akaike and Bayesian information criteria. The selection procedure indicated that a model with a random intercept and level-one autoregressive error correlation structure was the most optimal. Due to nonlinearity observed for the effect of time over the five repeated assessments for numerous outcomes, time was modelled as a categorical variable, allowing separate estimates of change between all assessment time points. *A priori* contrasts of interest for time were change from the preceding time-point, and total change from pre-surgery to 12 months post-surgery. To compare measures of PA and SB and measures related to weight between surgery type, models included a dummy variable for surgical type and an interaction term between time and surgery type. This allowed comparison of estimates of change over time between the two surgical procedures. Tables and Figures presented for each multilevel model include the estimate for each assessment time point using all available information, that is, using only those cases observed at that time point (observed mean) and also using the full sample, i.e. including cases missing at that time point (predicted mean). Regarding the exposure variation analysis data, only descriptive statistics were presented in this thesis. Inferential statistics for temporal changes in exposure variation analysis data require complex statistical methods involving compositional analysis which are beyond the scope of this thesis and are methods currently under development by the supervisory team.

The distribution of the DASS-21 score and the count variable apnoea-hypopnoea index (collected pre-surgery, and 3, 6, 9, and 12 months post-surgery) were right-skewed and change in these measures was analysed using a negative-binomial model utilising generalised estimating equations with a level-one autoregressive error correlation structure. Generalised estimating equations are an alternative method to multilevel regression models to account for the non-independence in the data (i.e. the repeated measures of each individual), which also result in unbiased estimates providing the correlation structure is correctly modelled (589). For both linear multilevel and negative binomial models, plots of change over time for each individual were examined to identify potential outliers and cases having potential undue influence over model estimates. The comparison of continuous, normally distributed data for variables measured only pre-surgery and 12 months post-surgery was done using paired sample *t*-tests. The comparison of categorical data for variables measured pre-surgery and 12 months post-surgery was done using McNemar's exact test.

The association between percentage of weight loss and pre- to 12 months post-surgery change in measures of PA and SB was analysed using linear regression analysis. The degree of change in each measure of PA and SB associated with a 10% increment of percentage weight loss was estimated. This association was analysed with and without adjustment for type of surgery. A p value ≤ 0.05 was considered statistically significant for all analyses. All data were expressed as mean (standard deviation) or median (interquartile range), unless otherwise stated. Change between assessment time points was reported as mean change in units of measurement for linear models, and as incidence rate ratios (i.e. proportional change) for negative binomial models, with 95% confidence intervals. The exposure variation analysis data were expressed in bouts of time (minutes) and as percentages of total average daily monitor wear time (i.e. waking hours).

3.2 Study 2

3.2.1 Study design

3.2.1.1 Overview

The study was longitudinal and qualitative in design. Data collection was undertaken between January 2013 and August 2014. Adults scheduled to undergo restrictive bariatric surgery were recruited from two private bariatric surgery clinics in Perth, Western Australia. Semi-structured interviews were conducted pre-surgery and 12 months post-surgery. The results from the pre-surgery interview are presented and discussed in Chapter 5 (Study 2(A) - Results and discussion). The results from the follow-up interview at 12 months post-surgery are presented and discussed in Chapter 6 (Study 2(B) - Results and discussion).

3.2.1.2 Approval from human research ethics committee

The study was approved by the Human Research Ethics Committee at Curtin University (approval number PT225/2012).

3.2.1.3 Participants

3.2.1.3.1 <u>Inclusion criteria</u>

Individuals were eligible to participate in the study if they were aged over 18 years, with BMI > 30 kg/m^2 and scheduled to undergo primary LAGB or LSG.

3.2.1.3.2 <u>Exclusion criteria</u>

Exclusion criteria comprised; (i) pregnancy or planning pregnancy within 12 months, (ii) presence of a permanent health condition such as a neurological, cardiovascular or orthopaedic disease that could compromise the performance of daily PA, and (iii) cognitive impairments or language barriers which could interfere with participation in the interviews.

3.2.2 Recruitment

Participants were recruited between January 2013 and July 2013 from two private bariatric surgery clinics in Perth. The recruitment process was as described in section 3.1.2 (Recruitment).

3.2.3 Assessment protocol

Data collection comprised semi-structured, one-on-one interviews pre-surgery, and 12 months post-surgery. Data collection took place between January and July of 2013 for the pre-surgery interview, and between February and August of 2014 for the post-surgery interview. The interviews were conducted by Juliana Zabatiero (JZ), at the bariatric surgery clinic rooms, a research room at Curtin University or over the phone, according to participants' preference, and audio-recorded with a digital recorder (IC Recorder, ICD-PX312; Sony Corporation, Tokyo, Japan).

3.2.3.1 Interview schedules

The interview schedule for the pre-surgery interview (see Appendix 1) was based on findings from previous research that had explored barriers and facilitators to PA among obese adults (215, 219), as well as in consultation with bariatric surgeons, physiotherapists and health psychology academics. Open-ended questions focused on the participants' beliefs about PA (i.e. health benefits of PA, what qualifies someone as physically active), as well as their perceived barriers and facilitators to PA. During the interview, clarification (e.g. What do you mean when you say…?) and elaboration probes (e.g. Can you give me an example of…?), as well as paraphrasing were used to prompt participants and optimise clarity and depth of data.

The interview schedule for the follow-up interview at 12 months post-surgery (see Appendix 2) also used open-ended questions that focused on the potential changes in participants' engagement in PA, perceived ability to engage in PA, perceived barriers and facilitators, as well as their perceived motivators to PA. Opening questions explored participants' perceptions of any changes in their participation in PA and were followed by more direct questions, which were informed by findings from the pre-surgery interview. Similarly to the pre-surgery interview, clarification probes, elaboration probes, and paraphrasing were used to prompt participants and optimise clarity and depth of data.

3.2.4 Data analysis

The interview audio-recordings, for both pre- and post-surgery interviews, were transcribed verbatim and entered into NVivo10 (QSR International Pty Ltd, version 10, 2012) to facilitate data organisation, coding, and management. Data analysis was performed concurrently with data collection to monitor the emergence of new themes. Recruitment ceased when data saturation was achieved (i.e. no new themes emerged).

Thematic analysis is a widely used and flexible method to identify, describe, analyse and report patterns (themes) within qualitative data (590). A theme is a pattern found in the data that can initially describe and organise observations, and further provide interpretations of a phenomenon (591). Since thematic analysis provides a rich and detailed account of qualitative data, and can be performed independently of any theoretical framework (590), it was deemed the most appropriate approach to analyse data from the interviews collected in this study.

There are two primary ways to identify patterns within the data when using thematic analysis (590). An inductive approach means that the analysis is data-driven, that is, the identified themes are linked to the data themselves, whereas a deductive approach seeks to provide a description and interpretation of themes, often relating to findings from previous studies or existing theories, in order to identify patterns related to a specific research question (590). In this study, an integrated approach of inductive and deductive thematic analysis was employed in order to identify codes and themes from the participants' discourse (i.e. inductively) that reflected broader deductive categories (e.g. perceived barriers to PA). The process of data analysis followed steps proposed by Braun and Clarke (590), and is described in more detail bellow.

3.2.4.1 Familiarity and closeness to the data

Familiarity and closeness to the data were certified through the collection of data, transcription of interviews, and reading and re-reading of transcripts with an active approach (i.e. searching for meanings and patterns within the data). The transcription of interviews was done partly by the interviewer (around 20% of the data collected), with the remaining performed by a professional transcribing service. Around half of the professional service's transcriptions were checked against the audio-recordings to ensure the original meaning was retained. During this process of familiarisation, notes were taken regarding potential codes present in the data.

3.2.4.2 Coding

After becoming familiar with the data, the next step was to generate initial codes. Codes can be described as labels that capture a meaningful aspect of the data (591). Coding was conducted line-by-line in order to compare and contrast similarities and differences in the data, and individual extracts were coded for as many potential themes as deemed appropriate. Data extracts were considered meaningful when they were related to any of the deductive categories. Labels were then allocated to the data extracts to assist in the process of grouping related concepts within the participants' discourse.

3.2.4.3 Identification of themes

The process of grouping similar codes into themes was finalised after all transcripts were coded. The codes generated were sorted and initially combined under one or more potential themes within each of the broad deductive categories, and further arranged to better illustrate the overarching themes.

3.2.4.4 Revision of themes

The initial themes identified from the data were reviewed and refined in order to assure that they presented a coherent pattern of data. For instance, regarding the pre-surgery interview data, under the category of beliefs about PA, initial themes such as 'PA maintains your muscle strength' and 'PA maintains fitness' were combined into the theme of 'physical health benefits of PA'. Central to this process was exploring how codes were similar to but different from others (e.g. the theme 'PA maintains your muscles toned' is related to physical appearance, while the theme 'PA maintains fitness' is related to people's capacity to engage in PA; however, both were included into a broader theme of physical benefits of PA). After the review and refinement of individual themes, a thematic map was generated and the themes were reviewed and considered against the entire data set to ensure they accurately reflected the meanings evident in the data as a whole.

To enhance the trustworthiness of the analysis process, the interpretation of the themes during the 'identification of themes' step were checked against the raw data to ensure that it reflected the discourse of participants. The final thematic map generated at the end of the 'revision of themes' step was also checked against the raw data to ensure the credibility of the analysis. A second analyst, experienced with thematic analysis, independently analysed randomly selected transcripts from 30% of the sample to ascertain the credibility of the primary analyst's (JZ) interpretation of the raw data. When comparing the independent analyses, inter-rater reliability was approximately 90% for codes and themes identified; discrepancies were clarified through discussions regarding possible interpretations of each code. Final themes and interpretations were discussed with supervisors, who served as a sounding board for the data analysis and exploration of alternative explanations and interpretations of the participants' discourse.

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CHAPTER 4 STUDY 1 - RESULTS AND DISCUSSION

Overview

This chapter presents the results and discussion of the outcomes related to Study 1. The methods relating to this study, including the description of study design, inclusion and exclusion criteria, recruitment process, assessment protocol, and data analyses have been described in Chapter 3 (section 3.1 Study 1). Section 4.1 describes the study participants and presents data pertaining to changes, over the first year following restrictive bariatric surgery, in the primary and secondary outcome measures. For section 4.1 data are first presented pertaining to change in the primary outcome measures of physical activity (PA) and sedentary behaviour (SB). Thereafter, data are presented pertaining to change in the secondary outcomes relevant to PA, including measures of cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, body composition and bone mineral density (BMD). Finally, data are presented pertaining to change in the secondary outcomes used to confirm the efficacy of bariatric surgery, including measures of weight, obesity-related comorbid conditions, health-related quality of life (HRQoL), obesity-related quality of life and weight-related symptoms, and symptoms of mental health disorders. Section 4.2 discusses the results presented for this study.

The specific research questions answered in this chapter are:

(i) Compared with measures collected pre-surgery, what is the magnitude of change in measures of PA and SB collected over the first 12 months following restrictive bariatric surgery?

(ii) Compared with measures collected pre-surgery, what is the magnitude of change in measures of cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, and body composition and BMD, collected over the first 12 months following restrictive bariatric surgery?

(iii) Compared with measures collected pre-surgery, what is the magnitude of change in measures of weight, obesity-related comorbid conditions, HRQoL, obesity-related quality of life and weight-related symptoms, and symptoms of depression, anxiety and stress; and (iv) does the magnitude of change in measures of weight differ between laparoscopic sleeve gastrectomy (LSG) in comparison to laparoscopic adjustable gastric banding (LAGB) over the first 12 months following restrictive bariatric surgery?

4.1 Results

4.1.1 Participants

Between April 2013 and June 2014, a total of 279 people who were obese were screened to participate, of whom 180 (65%) were considered eligible. Thirty-six of the 180 eligible people agreed to participate. Six (17%) of them withdrew before the pre-surgery assessment, and 30 (83%) provided written informed consent and were included in the study. A study flowchart is provided in Figure 4.1. The characteristics of participants at the pre-surgery assessment time point are presented in Table 4.1.

The average length of hospital stay was 2.1 days (standard deviation [SD], 0.3) and there were no peri-operative or early post-operative complications. One participant underwent a hip replacement 5 months post-surgery, and another participant underwent a prostatectomy 9 months post-surgery. One participant who underwent LSG withdrew from this study before completing the 6-month assessment. All assessments were done, on average, within a 2-week range from the assessment time points, with the exception of nine participants that were assessed around one month prior to surgery for the pre-surgery assessment, and one participant assessed 5 weeks after their 9-month assessment date.

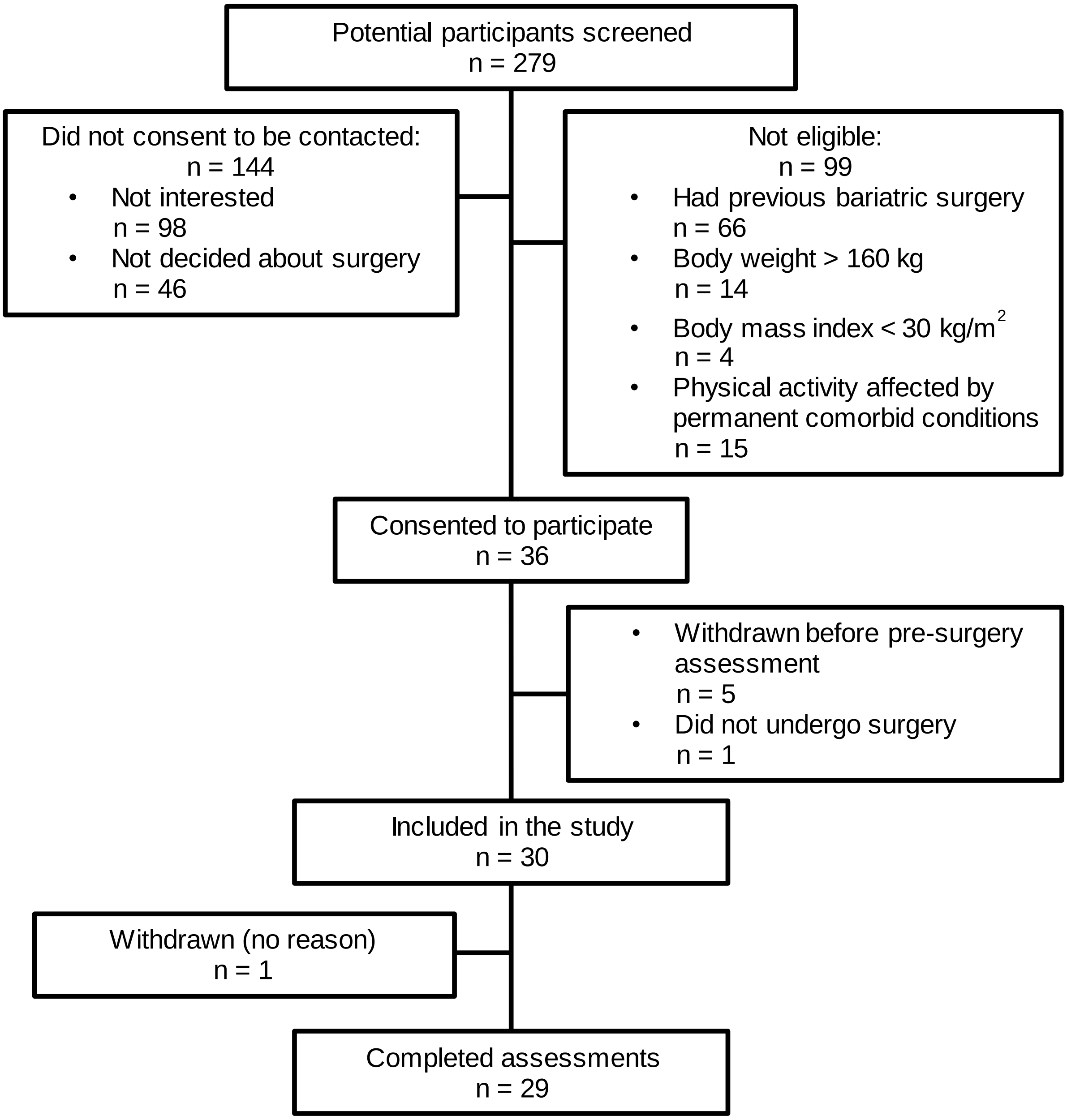

Figure 4.1. Study 1 flowchart.

Table 4.1. Characteristics of participants at the pre-surgery assessment

Characteristic	Combined group (n = 30)	LSG (n = 22)	LAGB (n = 8)
		Mean (range)	
Age (yr)	44.1 (22.0 – 65.0)	43.3 (22 – 65)	46.3 (32.0 – 54.0)
Height (m)	1.7 (1.5 – 1.9)	1.7 (1.5 – 1.9)	1.7 (1.5 – 1.8)
Weight (kg)	114.6 (84.1 – 154.3)	111.0 (84.1 – 133.5)	124.7 (93.9 – 154.3)
Body mass index (kg/m^2)	39.6 (30.9 – 50.9)	38.4 (30.9 – 47.7)	42.8 (33.8 – 51.0)
		n (%)	
Gender (Male/Female)	10 (33)/20 (67)	6 (20)/16 (54)	4 (13)/4 (13)
Smokers	2 (7)	2 (7)	0 (0)
Class I obesity	8 (27)	7 (23)	1 (3)
Class II obesity	8 (27)	6 (20)	2 (7)
Class III obesity	14 (46)	9 (30)	5 (17)
Medication use		**n (%)**	
Diabetes mellitus type 2	3 (10)	1 (3)	2 (7)
Hypertension	6 (20)	3 (10)	3 (10)
Dyslipidaemia	2 (7)	2 (7)	0 (0)

Abbreviations: LAGB: laparoscopic adjustable gastric banding; LSG: laparoscopic sleeve gastrectomy; SD: standard deviation.

4.1.2 Physical activity and sedentary behaviour

This section provides data pertaining to change in the primary outcome measures of PA and SB, collected pre-surgery, and 3, 6, 9 and 12 months post-surgery in order to answer research question (i). Participants wore the SenseWear Armband (SAB) for an average of 5.7 days (SD, 1.1) pre-surgery, 6.0 days (SD, 1.0) at 3 months, 5.6 days (SD, 0.8) at 6 months, 6.1 days (SD, 1.1) at 9 months, and 6.0 days (SD, 1.0) at 12 months post-surgery. The average daily wear time for the SAB was 16.3 hours/day (SD, 2.4) pre-surgery, 15.2 hours/day (SD, 1.5) at 3 months, 15.0 hours/day (SD, 1.5) at 6 months, 15.0 hours/day (SD, 1.0) at 9 months, and 15.1 hours/day (SD, 1.1) at 12 months post-surgery. Participants wore the StepWatch 3 Activity Monitor (SAM) for an average of 6.6 days (SD, 0.9) pre-surgery, 6.6 days (SD, 0.6) at 3 months, 6.5 days (SD, 0.9) at 6 months, 6.5 days (SD, 0.8) at 9 months, and 6.5 days (SD, 1.0) at 12 months post-surgery.

Total time spent in sedentary behaviour, light intensity physical activity and moderate to vigorous intensity physical activity

Table 4.2 presents data pertaining to change in the percentage of waking hours spent in SB, light intensity PA, and moderate to vigorous intensity PA (MVPA). Figures 4.2 to 4.4 present data collected at each assessment time point for the percentage of waking hours spent in SB, light intensity PA, and MVPA, respectively, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was no change in the percentage of waking hours spent in SB (mean change, -2%; 95% confidence interval [CI], -6 to 3), light intensity PA (mean change, 1% ; 95% CI, -3 to 5), or MVPA (mean change, 1%; 95% CI, -1 to 3). Figure 4.5 presents the data collected for each participant, at each assessment time point, for the percentage of waking hours spent in SB, light intensity PA, and MVPA, and shows the variability within the individual participant data. For instance, participant 10 presented no change in the percentage of waking hours spent in SB, light intensity PA and MVPA over the five assessment time points, while participant 3 presented a reduction in the percentage of waking hours spent in SB and an increase in the percentage of waking hours spent in light intensity PA between the pre-surgery and the 6-month post-surgery assessments, which were not maintained up to 12 months post-surgery. Similar results were found when total time spent in SB, light intensity PA and MVPA were reported as minutes/day (Appendix 3).

When participants were grouped according to surgery type, no difference was found in the change in time spent in SB, light intensity PA and MVPA, reported as both percentage of waking hours and minutes/day, between those who underwent LSG and LAGB (Appendix 4).

Associations between pre- to 12 months post-surgery measures of PA and SB and the percentage of weight loss were analysed using linear regression analysis (Appendix 5). When the association of change in each measure of PA and SB (i.e. daily step count, min/day spent in light intensity PA, min/day spent in MVPA and min/day spent in SB) with a 10% increment of percentage weight loss was estimated, both unadjusted and adjusted by type of surgery, the only significant association identified was an association of less steps/day with more weight loss (-1993 steps/day; 95% CI, -3188 to -798; $p = 0.002$), which was unaffected by adjustment for type of surgery (-2309 steps/day; 95% CI, -3738 to -880; $p = 0.003$).

Table 4.2. Change in the total time (percentage of waking hours) spent in sedentary behaviour, light intensity physical activity, and moderate to vigorous intensity physical activity

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Sedentary behaviour (% of waking hours)					
Pre-surgery	30	74 (11)	74	---	---
3 months	27	72 (11)	71	-2 (-5 to 0)	0.06
6 months	28	71 (13)	70	-1 (-4 to 2)	0.42
9 months	24	72 (9)	70	0 (-3 to 3)	0.96
12 months	20	73 (9)	72	2 (-1 to 5)	0.29
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-2 (-6 to 3)	0.44
Light intensity physical activity (% of waking hours)					
Pre-surgery	30	21 (9)	21	---	---
3 months	27	23 (10)	23	2 (0 to 4)	0.08
6 months	28	22 (10)	23	0 (-2 to 2)	0.94
9 months	24	21 (7)	22	-1 (-3 to 2)	0.64
12 months	20	21 (7)	22	0 (-3 to 2)	0.79
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				1 (-3 to 5)	0.56
Moderate to vigorous intensity physical activity (% of waking hours)					
Pre-surgery	30	5 (3)	5	---	---
3 months	27	6 (4)	6	0 (-1 to 2)	0.43
6 months	28	7 (6)	7	1 (0 to 2)	0.11
9 months	24	7 (5)	7	0 (-1 to 2)	0.52
12 months	20	6 (4)	6	-1 (-3 to 0)	0.08
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				1 (-1 to 3)	0.56

Abbreviations: CI: confidence interval; SD: standard deviation. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]) and only data from participants who met the minimal monitor wear requirements were included in the analyses (see section 3.1.5.2.2 for definition of minimal monitor wear requirements).

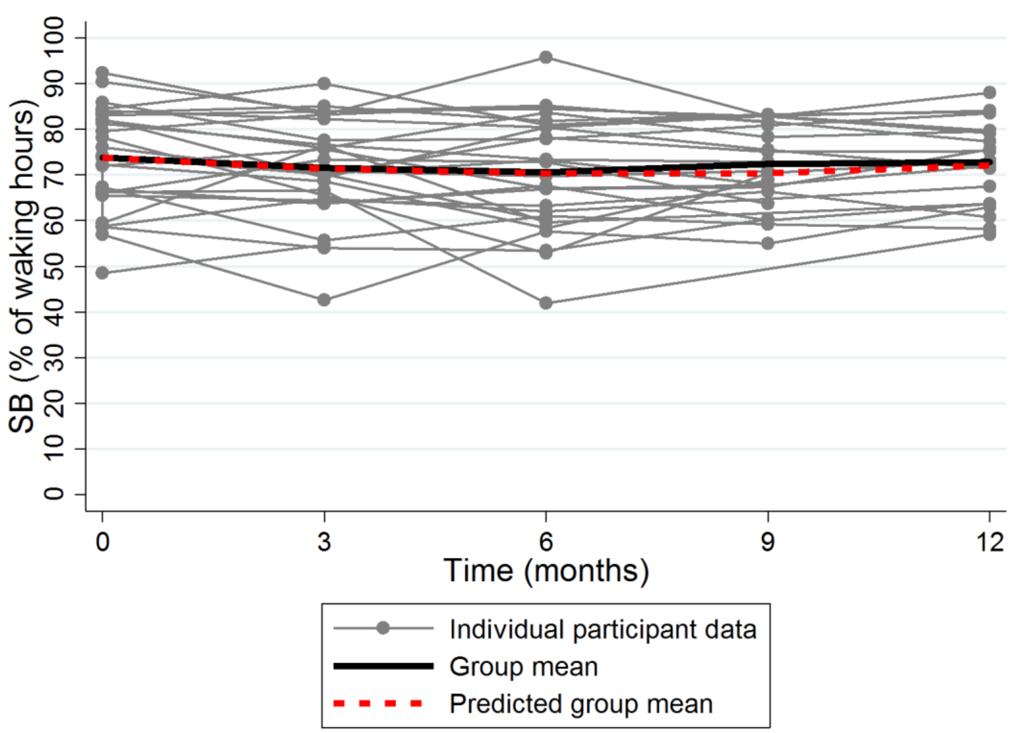

Figure 4.2. Data collected at each assessment time point for percentage of waking hours spent in sedentary behaviour (SB). The pre-surgery assessment time point is denoted by 0 months.

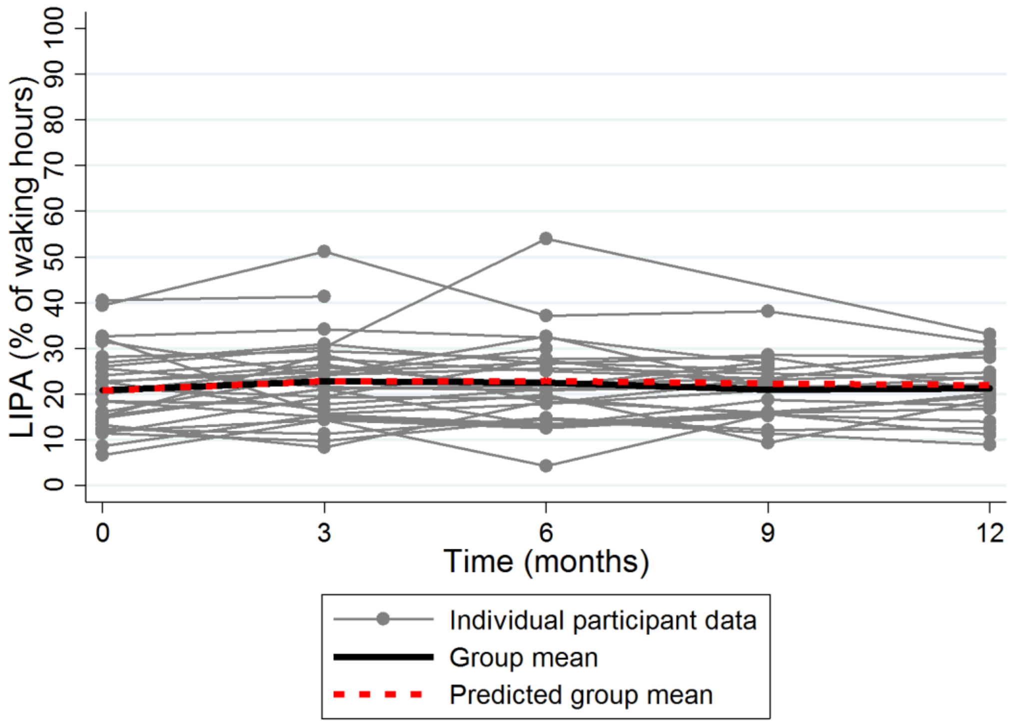

Figure 4.3. Data collected at each assessment time point for percentage of waking hours spent in light intensity physical activity (LIPA). The pre-surgery assessment time point is denoted by 0 months.

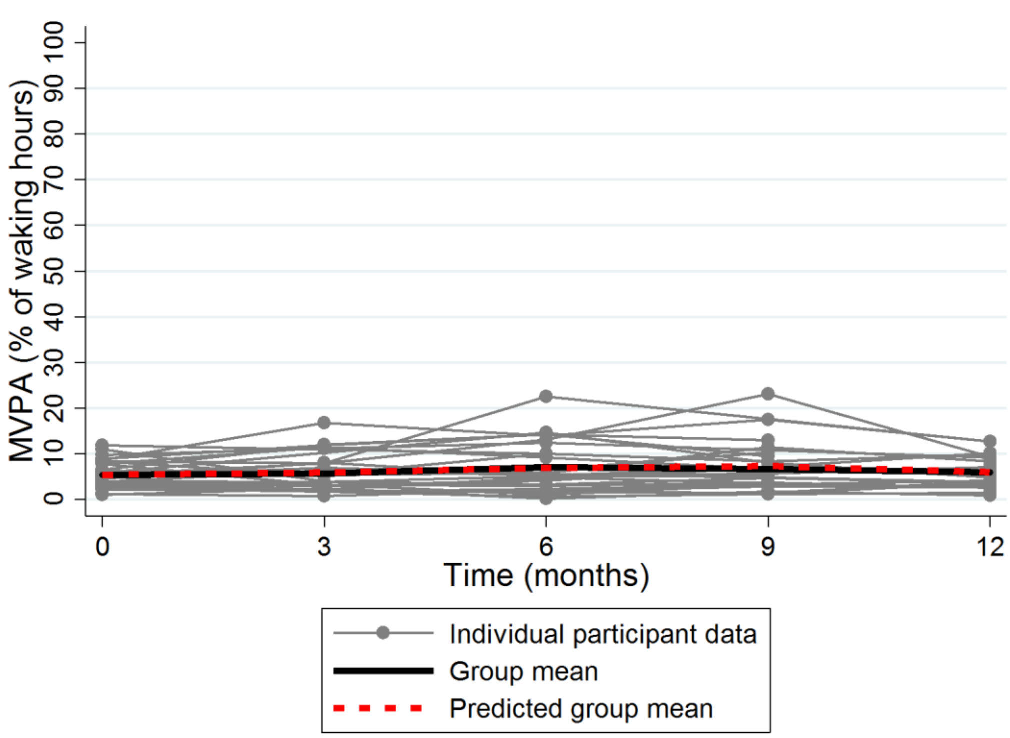

Figure 4.4. Data collected at each assessment time point for percentage of waking hours spent in moderate to vigorous intensity physical activity (MVPA). The pre-surgery assessment time point is denoted by 0 months.

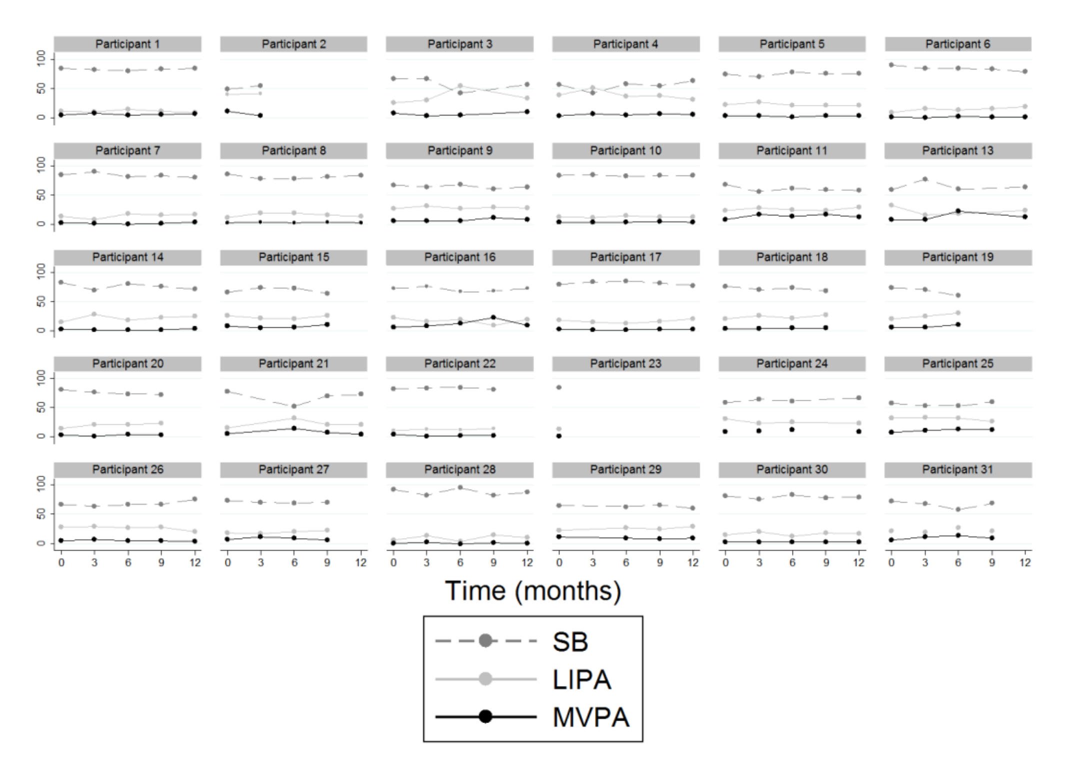

Figure 4.5. Data collected for each participant, at each assessment time point, for percentage of waking hours spent in sedentary behaviour (SB), light intensity physical activity (LIPA), and moderate to vigorous intensity physical activity (MVPA). The pre-surgery assessment time point is denoted by 0 months. Gaps in the individual participant graphs denote the absence of valid data for the measure at the specific assessment time point.

Accumulation of sedentary behaviour and physical activity in bouts of uninterrupted time

This sub-section provides descriptive data on how the percentage of waking hours spent in SB, light intensity PA and MVPA was accumulated. Table 4.3 presents data on the accumulation of SB, light intensity PA, and MVPA, for each assessment time point, in bouts of uninterrupted time ranging from 0 to < 5 minutes, 5 to < 10 minutes, 10 to < 30 minutes, 30 to < 60 minutes, and ≥ 60 minutes, and Figure 4.6 presents these data graphically to facilitate interpretation. Table 4.3 and Figure 4.6 show that across all assessment time points, participants spent most of their waking hours in SB, which was accumulated mostly in uninterrupted bouts of ≥ 30 minutes, and little of their waking hours in light intensity PA and MVPA, accumulated mostly in short periods of < 10 minutes.

Table 4.3. Accumulation of sedentary behaviour, light intensity physical activity, and moderate to vigorous intensity physical activity in bouts of uninterrupted time

Assessment time point	0 to < 5 minutes Mean (SD)	5 to < 10 minutes Mean (SD)	10 to < 30 minutes Mean (SD)	30 to < 60 minutes Mean (SD)	≥ 60 minutes Mean (SD)
Sedentary behaviour (% of waking hours)					
Pre-surgery	7 (3)	6 (3)	17 (5)	18 (7)	25 (16)
3 months	8 (3)	6 (2)	17 (6)	17 (6)	24 (16)
6 months	8 (3)	6 (3)	18 (6)	17 (7)	22 (18)
9 months	8 (3)	7 (2)	19 (6)	18 (6)	21 (14)
12 months	7 (3)	6 (3)	19 (5)	18 (5)	23 (17)
Light intensity physical activity (% of waking hours)					
Pre-surgery	12 (4)	6 (3)	3 (3)	0 (0)	0 (0)
3 months	12 (4)	6 (3)	4 (4)	0 (1)	0 (0)
6 months	12 (4)	6 (3)	4 (5)	1 (2)	0 (0)
9 months	12 (4)	5 (2)	4 (3)	0 (1)	0 (0)
12 months	12 (4)	6 (2)	4 (2)	0 (0)	0 (0)
Moderate to vigorous physical activity (% of waking hours)					
Pre-surgery	4 (2)	1 (1)	1 (1)	0 (0)	0 (1)
3 months	4 (2)	1 (1)	1 (1)	0 (0)	0 (0)
6 months	4 (3)	1 (2)	1 (1)	0 (1)	0 (1)
9 months	3 (2)	1 (1)	1 (2)	0 (1)	0 (0)
12 months	4 (2)	1 (1)	1 (1)	0 (0)	0 (0)

Abbreviations: SD: standard deviation. At each assessment time point, only data from participants who met the minimal monitor wear requirements were included in the analyses (see section 3.1.5.2.2 for definition of minimal monitor wear requirements).

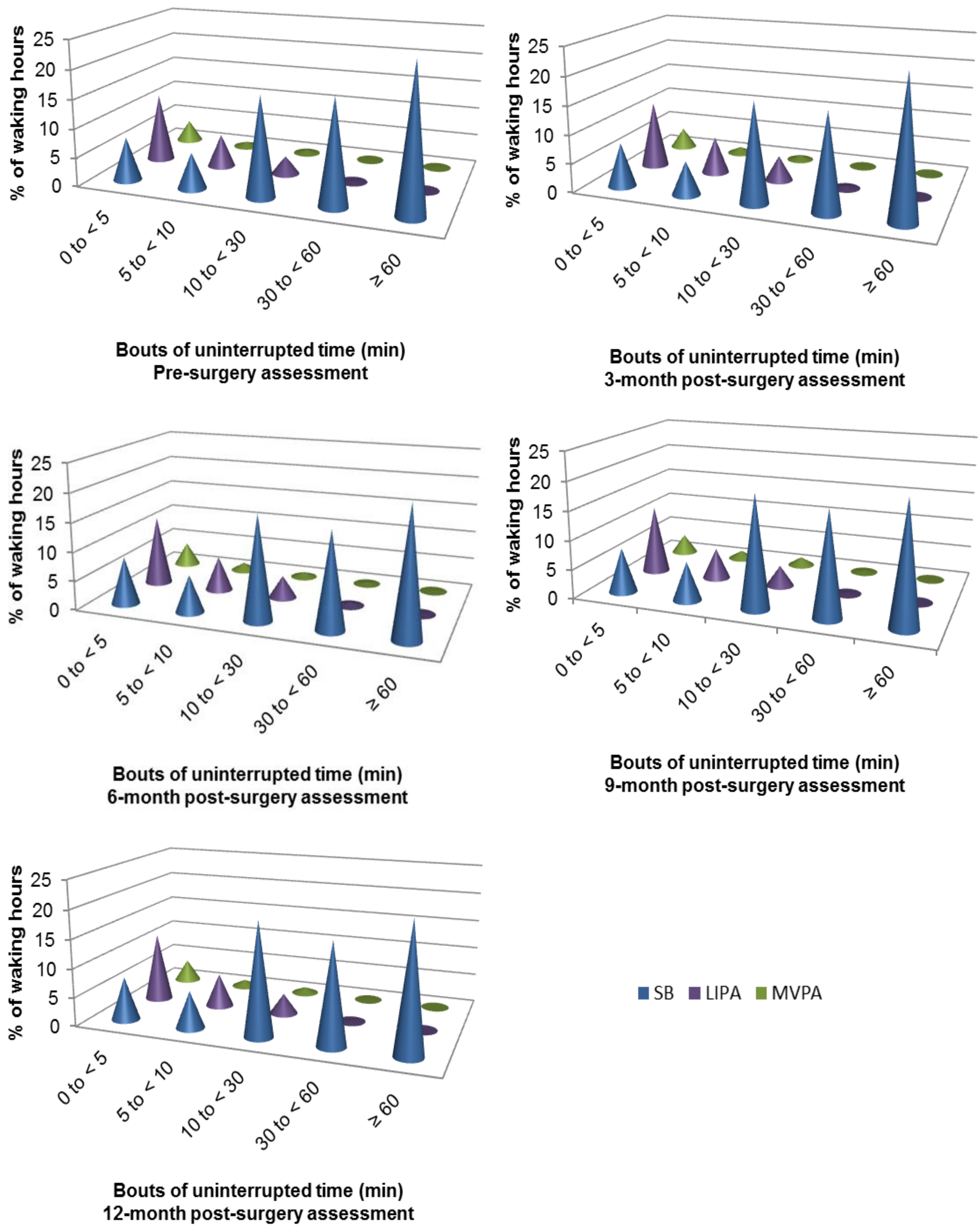

Figure 4.6. Percentage of waking hours spent in sedentary behaviour (SB), light intensity physical activity (LIPA), and moderate to vigorous intensity physical activity (MVPA), for each assessment time point, accumulated in bouts of uninterrupted time.

Table 4.4 presents data on the accumulation of SB in uninterrupted bouts ≥ 10 minutes and ≥ 30 minutes as a percentage of total time spent in SB and of MVPA in bouts < 10 minutes as a percentage of total time spent in MVPA. Figures 4.7 and 4.8 present these data collected at each assessment time point for the accumulation of SB and MVPA, respectively, with the addition of plots for individual participants to depict individual variability. Table 4.4 and Figure 4.7 show that at all assessment time points, most of the time spent in SB (i.e. ≥ 78%) was accumulated in uninterrupted bouts of ≥ 10 minutes and more than half of the time spent in SB (i.e. ≥ 51%) was accumulated in uninterrupted bouts of ≥ 30 minutes. Table 4.4 and Figure 4.8 show that at all assessment time points, the majority of the time spent in MVPA (i.e. ≥ 82%) was accumulated in short bouts of < 10 minutes. Data on the accumulation of SB in uninterrupted bouts of < 10 minutes and MVPA in uninterrupted bouts of ≥ 10 minutes is presented in Appendix 6.

Table 4.4. Accumulation of sedentary behaviour in uninterrupted bouts ≥ 10 minutes and ≥ 30 minutes and of moderate to vigorous physical activity in bouts < 10 minutes

Assessment time point	n	SB (% of total SB in bouts ≥ 10 minutes) Mean (SD)	SB (% of total SB in bouts ≥ 30 minutes) Mean (SD)	MVPA (% of total MVPA in bouts <10 minutes) Mean (SD)
Pre-surgery	30	80 (11)	56 (17)	88 (14)
3 months	27	80 (10)	55 (19)	88 (15)
6 months	28	78 (11)	52 (19)	86 (14)
9 months	24	79 (9)	51 (17)	82 (15)
12 months	20	80 (10)	53 (18)	86 (14)

Abbreviations: MVPA: moderate to vigorous physical activity; SB: sedentary behaviour. At each assessment time point, only data from participants who met the minimal monitor wear requirements were included in the analyses (see section 3.1.5.2.2 for definition of minimal monitor wear requirements).

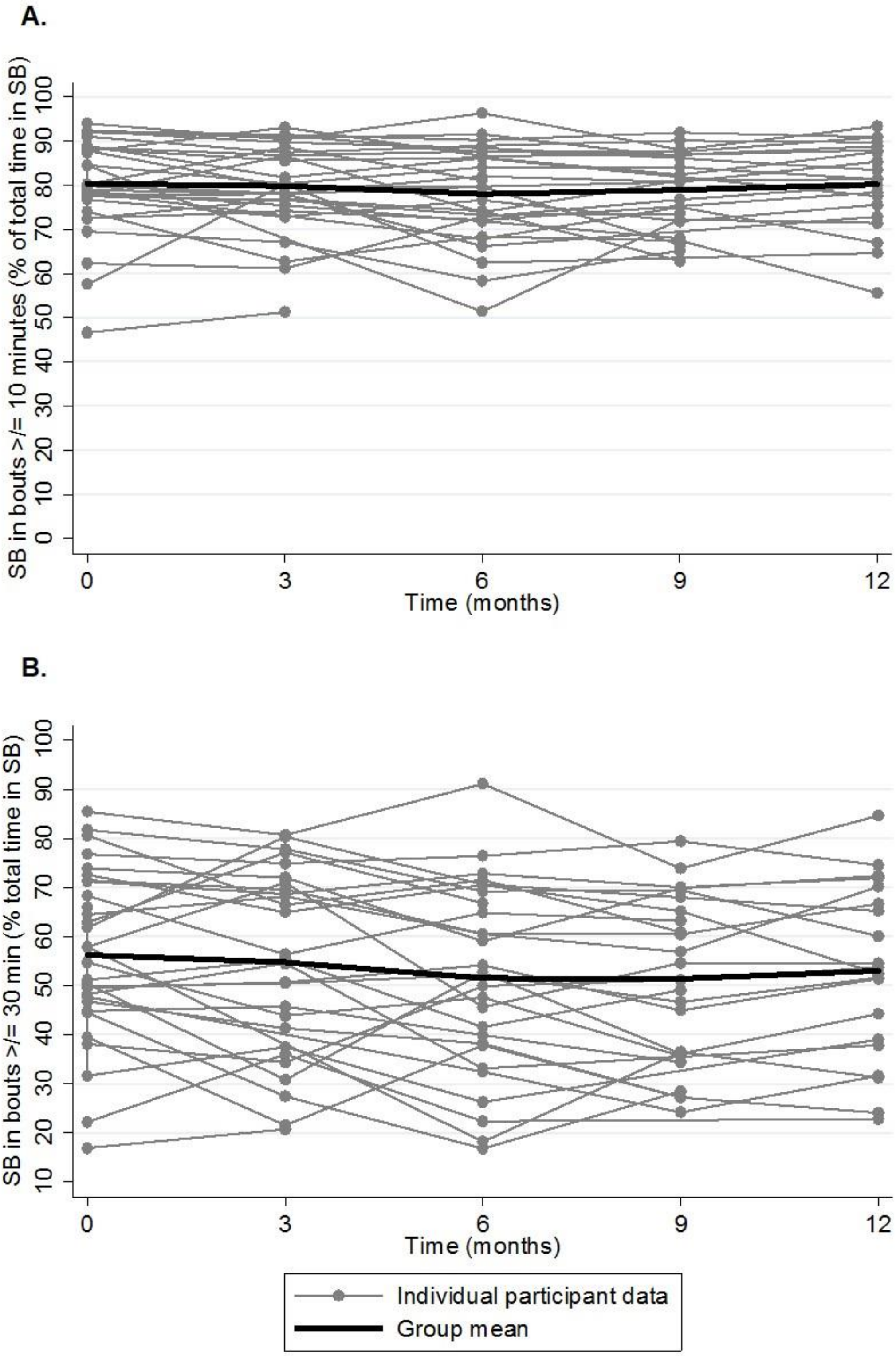

Figure 4.7. Data collected at each assessment time point for percentage of total time spent in sedentary behaviour (SB) accumulated in bouts (A) ≥ 10 minutes and (B) ≥ 30 minutes. The pre-surgery assessment time point is denoted by 0 months.

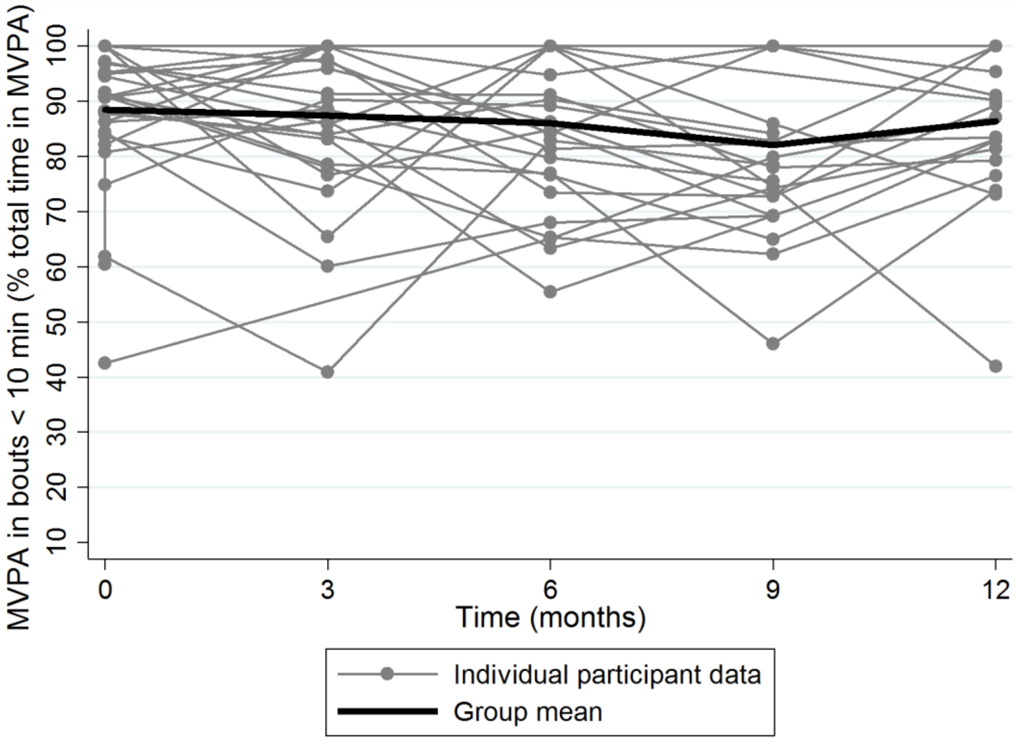

Figure 4.8. Data collected at each assessment time point for percentage of total time spent in moderate to vigorous physical activity (MVPA) accumulated in bouts < 10 minutes. The pre-surgery assessment time point is denoted by 0 months.

Daily step count

Table 4.5 presents data pertaining to change in the daily step count. Figure 4.9 presents data collected at each assessment time point for the daily step count, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was no change in the daily step count (mean change, 775 steps/day; 95% CI, -741 to 2291). When participants were grouped according to surgery type, no difference was found in the change in daily step count between those who underwent LSG and LAGB (Appendix 7).

Table 4.5. Change in daily step count

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Daily step count (steps/day)					
Pre-surgery	29	8122 (3543)	8042	---	---
3 months	27	8578 (3195)	8575	533 (-406 to 1471)	0.26
6 months	26	9280 (3594)	9038	463 (-494 to 1420)	0.34
9 months	26	8713 (2677)	9164	126 (-848 to 1099)	0.80
12 months	22	8871 (2842)	8817	-347 (-1397 to 702)	0.51
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				775 (-741 to 2291)	0.31

Abbreviations: CI: confidence interval; SD: standard deviation. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]) and only data from participants who met the minimal monitor wear requirements were included in the analyses (see section 3.1.5.2.2 for definition of minimal monitor wear requirements).

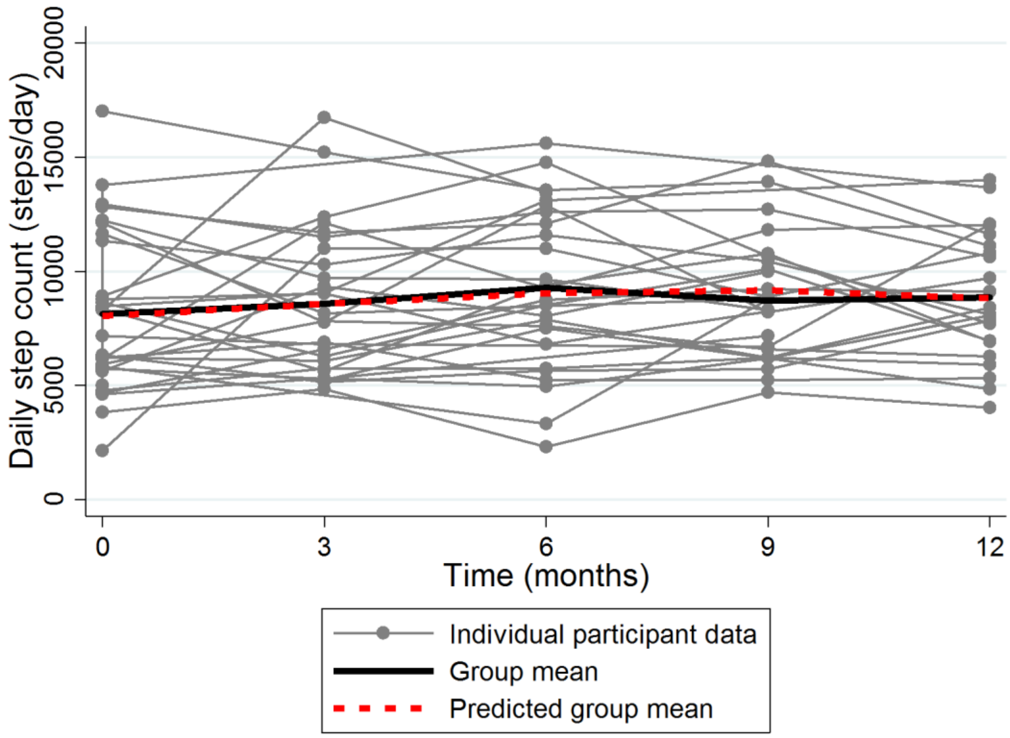

Figure 4.9. Data collected at each assessment time point for daily step count. The pre-surgery assessment time point is denoted by 0 months.

The following sections provide data pertaining to change in secondary outcome measures. A summary of descriptive data on changes in secondary outcome measures with participants grouped according to surgery type is presented in Appendix 8.

4.1.3 Cardiovascular fitness

This section provides data pertaining to change in measures of cardiovascular fitness collected pre-surgery and 12 months post-surgery in order to answer research question (ii). Table 4.6 presents data pertaining to change in cardiovascular fitness measured using the Physical Working Capacity 170 test (PWC-170). Compared to pre-surgery measures, 12 months post-surgery, there was no change in the mean estimated load required to achieve a heart rate of 170 beats per minute in the test.

Table 4.6. Change in cardiovascular fitness

Assessment time point	n	Observed Mean (SD)	Mean change (95%CI)	p-value
Cardiovascular fitness (PWC-170 [Watts])				
Pre-surgery	16	194 (64)	---	---
12 months	16	210 (52)	16 (-7 to 39)	0.14

Abbreviations: CI: confidence interval; SD: standard deviation. Comparison done using paired samples t-test.

4.1.4 Self-efficacy to exercise

This section provides data pertaining to change in measures of self-efficacy to exercise collected pre-surgery, and 3, 6, 9 and 12 months post-surgery in order to answer research question (ii). Table 4.7 presents data pertaining to change in self-efficacy to exercise measured using the Exercise Self-Efficacy Scale (ESES). Figure 4.10 presents data collected at each assessment time point for self-efficacy to exercise, expressed by the ESES score, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was an increase in the self-efficacy to exercise (mean change, 18.9; 95% CI, 11.3 to 26.5). Table 4.7 and Figure 4.10 show that the majority of change in self-efficacy to exercise occurred in the first 3 months, and was maintained up to 12 months post-surgery.

Table 4.7. Change in self-efficacy to exercise

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Self-efficacy to exercise (Exercise Self-Efficacy Scale score)					
Pre-surgery	30	53.4 (17.2)	53.4	---	---
3 months	30	67.2 (19.1)	67.2	13.8 (9.1 to 18.6)	< 0.001
6 months	29	71.4 (15.3)	71.4	4.2 (-0.6 to 9.0)	0.08
9 months	29	70.9 (14.8)	71.0	-0.4 (-5.3 to 4.4)	0.85
12 months	28	72.3 (18.3)	72.3	1.3 (-3.6 to 6.2)	0.60
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				18.9 (11.3 to 26.5)	< 0.001

Abbreviations: CI: confidence interval; SD: standard deviation. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]).

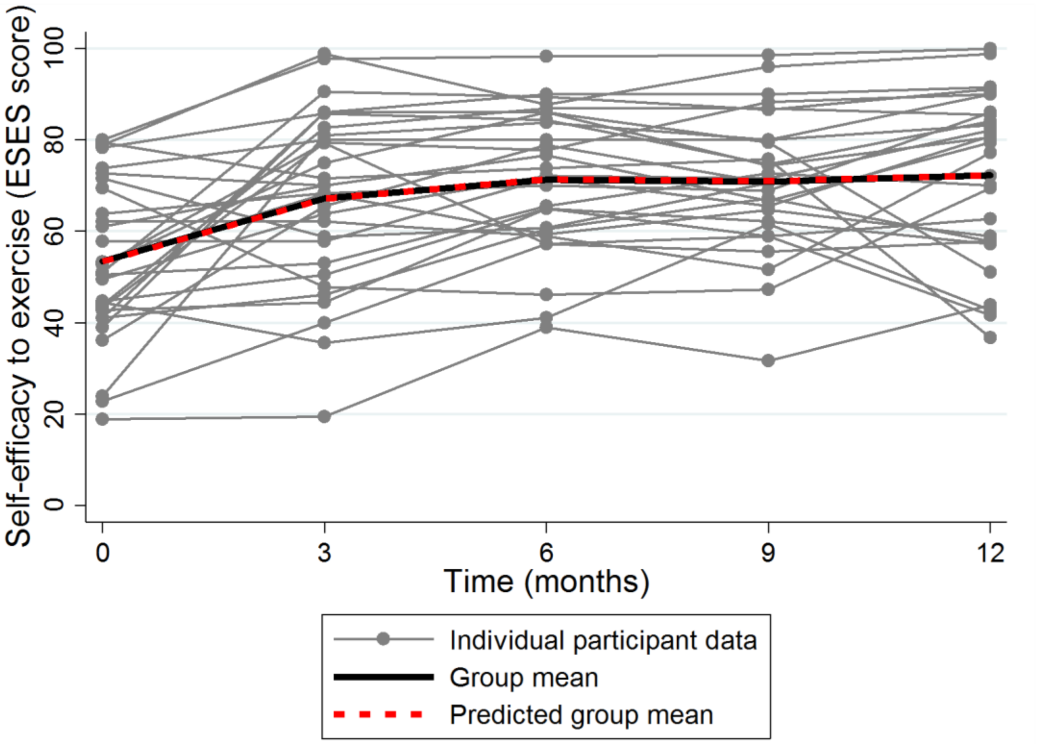

Figure 4.10. Data collected at each assessment time point for self-efficacy to exercise, expressed by the score of the Exercise Self-Efficacy Scale (ESES). The pre-surgery assessment time point is denoted by 0 months.

4.1.5 Sleep quality

This section provides data pertaining to change in measures of sleep quality collected pre-surgery, and 3, 6, 9 and 12 months post-surgery in order to answer research question (ii). Table 4.8 presents data pertaining to change in sleep quality measured using the Pittsburgh Sleep Quality Index (PSQI). Figure 4.11 presents data collected at each assessment time point for sleep quality, expressed by the PSQI score, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was an improvement in sleep quality (mean change, -3.1; 95% CI, -4.6 to -1.6). Table 4.8 and Figure 4.11 show that the majority of change in sleep quality occurred in the first 3 months, and was maintained up to 12 months post-surgery.

Table 4.8. Change in sleep quality

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Sleep quality (Pittsburgh Sleep Quality Index score)					
Pre-surgery	30	8.7 (2.9)	8.7	---	---
3 months	30	6.3 (3.6)	6.3	-2.5 (-3.4 to -1.5)	< 0.001
6 months	29	5.5 (4.0)	5.5	-0.8 (-1.7 to 0.2)	0.11
9 months	29	4.8 (3.2)	4.8	-0.8 (-1.7 to 0.2)	0.11
12 months	28	5.7 (3.5)	5.7	0.9 (-0.1 to 1.9)	0.06
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-3.1 (-4.6 to -1.6)	< 0.001

Abbreviations: CI: confidence interval; SD: standard deviation. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]).

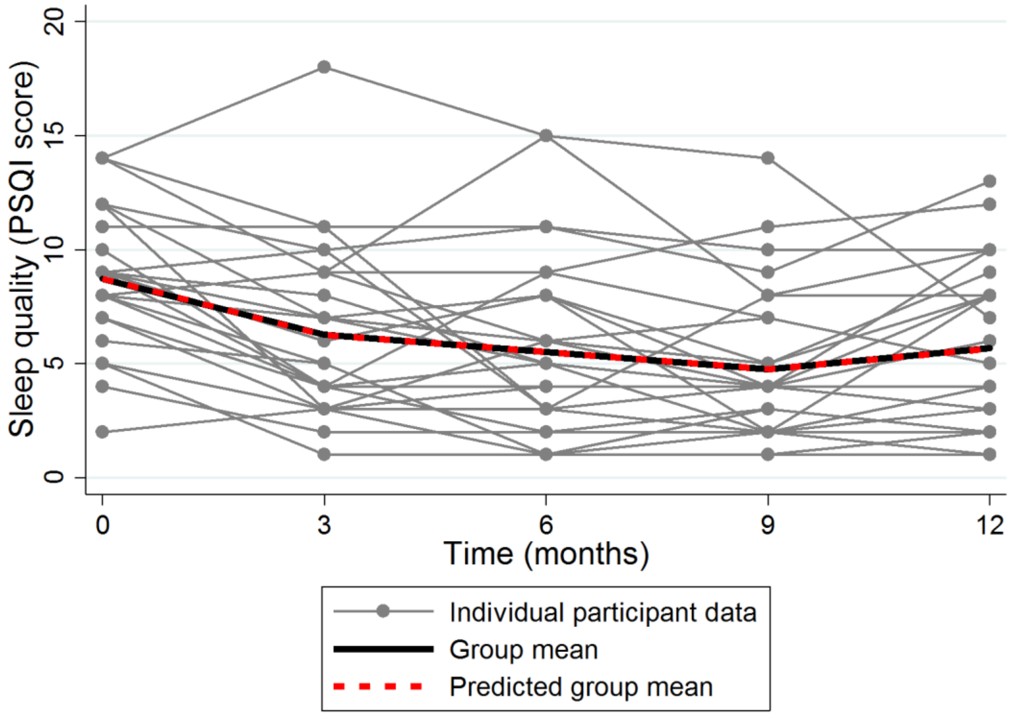

Figure 4.11. Data collected at each assessment time point for sleep quality, expressed by the score of the Pittsburgh Sleep Quality Index (PSQI). The pre-surgery assessment time point is denoted by 0 months.

4.1.6 Daytime sleepiness

This section provides data pertaining to change in measures of daytime sleepiness collected pre-surgery, and 3, 6, 9 and 12 months post-surgery in order to answer research question (ii). Table 4.9 presents data pertaining to change in daytime sleepiness measured using the Epworth Sleepiness Scale (ESS). Figure 4.12 presents data collected at each assessment time point for daytime sleepiness, expressed by the ESS score, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was a reduction in daytime sleepiness (mean change, -3.0; 95% CI, -1.3 to -4.7). Table 4.9 and Figure 4.12 show that the majority of change in daytime sleepiness occurred in the first 3 months, and was maintained up to 12 months post-surgery.

Table 4.9. Change in daytime sleepiness

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Daytime sleepiness (Epworth Sleepiness Scale score)					
Pre-surgery	30	8.5 (4.6)	8.5	---	---
3 months	30	5.8 (4.4)	5.8	-2.7 (-3.7 to -1.7)	< 0.001
6 months	29	4.9 (4.0)	5.1	-0.7 (-1.8 to 0.3)	0.15
9 months	29	5.3 (4.6)	5.4	0.3 (-0.7 to 1.4)	0.51
12 months	28	5.4 (3.7)	5.5	0.1 (-0.9 to 1.1)	0.86
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-3.0 (-4.7 to -1.3)	0.001

Abbreviations: CI: confidence interval; SD: standard deviation. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]).

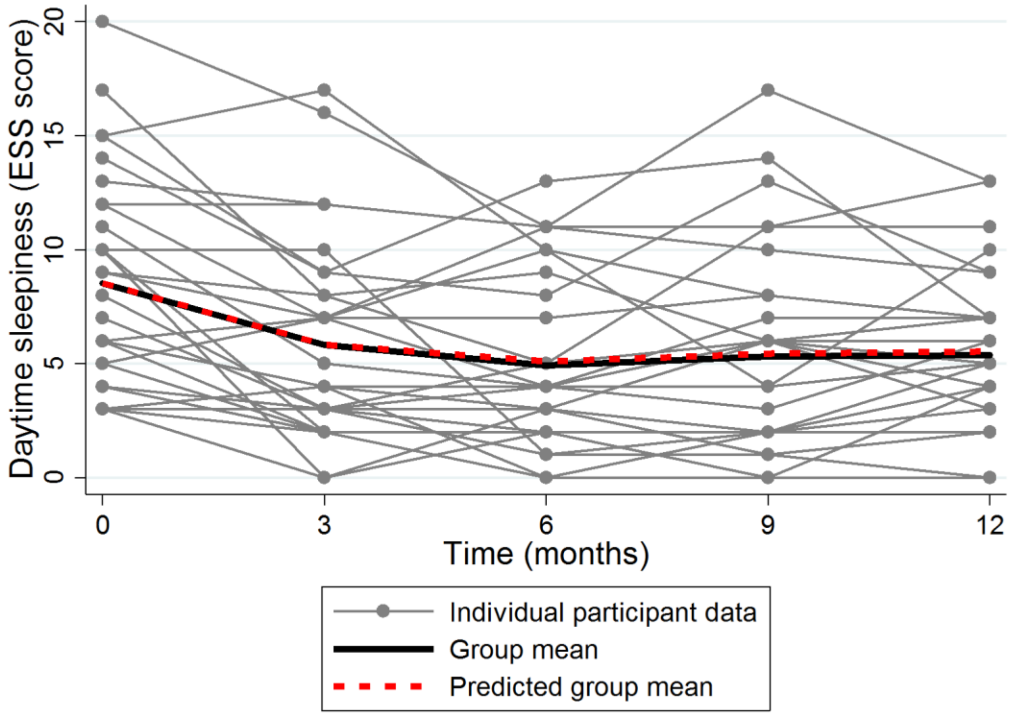

Figure 4.12. Data collected at each assessment time point for daytime sleepiness, expressed by the score of the Epworth Sleepiness Scale (ESS). The pre-surgery assessment time point is denoted by 0 months.

4.1.7 Body composition and bone mineral density

This section provides data pertaining to change in measures of body composition and BMD collected pre-surgery and 12 months post-surgery in order to answer research question (ii). Table 4.10 presents data pertaining to change in body composition and BMD, measured using whole-body dual energy x-ray absorptiometry scanning (DXA). Compared to pre-surgery measures, 12 months post-surgery, there were significant reductions in absolute and percentage fat mass (FM) and in absolute fat-free mass (FFM). Both pre-surgery and 12 months post-surgery, no participant presented with total body T-scores indicative of osteopenia (i.e. between -1 and -2.5 SD) or osteoporosis (i.e. below -2.5 SD) (592). Compared to pre-surgery measures, 12 months post-surgery, there were significant reductions in the regional BMD measures of the spine and pelvis.

Table 4.10. Change in body composition and bone mineral density

Measure	n	Pre-surgery Mean (SD)	12-month post-surgery Mean (SD)	Mean change (95% CI)	p-value
Body composition					
FM (kg)	26	55.7 (10.6)	33.8 (12.5)	-21.9 (-26.9 to -17.0)	< 0.001
FM (%)	26	49 (6)	39 (8)	-10 (-13 to -8)	< 0.001
FFM (kg)	26	59.4 (10.1)	54.2 (9.5)	-5.1 (-6.5 to -3.7)	< 0.001
FFM (%)	26	52 (6)	63 (8)	11 (8 to 14)	< 0.001
Bone mineral density					
Total body (g/cm^2)	26	1.26 (0.12)	1.26 (0.13)	0.00 (-0.02 to 0.02)	> 0.99
Total body T-score	26	1.45 (1.06)	1.39 (1.19)	-0.06 (-0.19 to 0.07)	0.36
Spine (g/cm^2)	26	1.33 (0.15)	1.24 (0.03)	-0.08 (-0.12 to -0.04)	< 0.001
Pelvis (g/cm^2)	26	1.13 (0.17)	1.08 (0.15)	-0.05 (-0.07 to -0.03)	< 0.001

Abbreviations: CI: confidence interval; FFM: fat-free mass; FM: fat mass; SD: standard deviation. All comparisons done using paired samples t-test.

4.1.8 Weight-related measures

This section provides data pertaining to change in weight-related measures collected pre-surgery, and 3, 6, 9 and 12 months post-surgery in order to answer research question (iii). Table 4.11 presents data pertaining to change in weight-related measures. Figures 4.13 and 4.14 present data collected at each assessment time point for body weight and body mass index (BMI), and weight expressed as the percentage of pre-surgery weight loss and as the percentage of excess weight loss (%EWL), respectively, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was a mean weight reduction of 27.9 kg (95% CI, 24.5 to 31.4), a mean BMI reduction of 9.7 kg/m^2 (95%, 8.5 to 10.9), a mean loss of 24% (95% CI, 21 to 28) of pre-surgery weight, and a mean %EWL of 72% (95% CI, 61 to 83). Table 4.11 and Figures 4.13 and 4.14 show that the majority of change in weight-related measures occurred in the first 3 months, with smaller changes up to 9 months, which were maintained up to 12 months post-surgery. Pre-surgery, eight (27%) participants were classified into class I obesity (i.e. BMI: 30 to 34.9 kg/m^2), eight (27%) into class II obesity (i.e. BMI: 35 to 39.9 kg/m^2), and 14 (47%) into class III obesity (i.e. BMI > 40 kg/m^2). At 12 months post-surgery, four (14%) participants reached the normal-weight range (i.e. BMI: 18.5 to 24.9 kg/m^2), 13 (45%) were classified as overweight (BMI: 25 to 29.9 kg/m^2), seven (24%) were classified into class I obesity, three (10%) into class II obesity, and two (7%) into class III obesity.

Compared to pre-surgery measures, 12 months post-surgery, participants had a mean waist circumference reduction of 22.7 cm (95% CI, 18.2 to 27.2). Pre-surgery, all participants presented waist circumference measures greater than the risk values determined by the World Health Organisation (i.e. > 88 cm for women and > 102 cm for men). At 12 months post-surgery, three (30%) of the 10 men and seven (35%) of the 20 women had waist circumference measures below the risk values.

Table 4.11. Change in weight-related measures

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
			Weight (kg)*		
Pre-surgery	30	114.6 (17.2)	114.6	---	---
3 months	30	95.9 (16.5)	96.0	-18.7 (-20.4 to -16.9)	< 0.001
6 months	30	89.7 (17.3)	89.7	-6.3 (-8.0 to -4.5)	< 0.001
9 months	29	87.4 (17.8)	86.8	-2.9 (-4.7 to -1.1)	0.001
12 months	28	88.2 (18.9)	86.7	-0.1 (-1.9 to 1.8)	0.95
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-27.9 (-31.4 to -24.5)	<0.001
			Body mass index (kg/m²)*		
Pre-surgery	30	39.6 (5.5)	39.6	---	---
3 months	30	33.1 (5.5)	33.1	-6.4 (-7.0 to -5.8)	< 0.001
6 months	30	30.9 (5.7)	30.9	-2.2 (-2.8 to -1.6)	< 0.001
9 months	29	30.2 (5.9)	29.9	-1.0 (-1.6 to -0.4)	0.001
12 months	28	30.4 (6.3)	29.9	-0.0 (-0.7 to 0.6)	0.91
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-9.7 (-10.9 to -8.5)	< 0.001
			% of pre-surgery weight loss*		
3 months	30	-16 (5)	-16	-16 (-20 to -13)	< 0.001
6 months	30	-22 (9)	-22	-5 (-7 to -4)	< 0.001
9 months	29	-24 (10)	-24	-3 (-4 to -1)	< 0.001
12 months	28	-24 (12)	-24	-0 (-1 to 1)	0.99
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-24 (-28 to -21)	< 0.001

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Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
% of excess weight loss*					
3 months	30	-49 (22)	-49	-49 (-60 to -38)	< 0.001
6 months	30	-65 (30)	-65	-16 (-19 to -12)	< 0.001
9 months	29	-71 (33)	-72	-7 (-10 to -4)	< 0.001
12 months	28	-69 (37)	-72	0 (-3 to 4)	0.89
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-72 (-83 to -61)	< 0.001
Waist circumference (cm)†					
Pre-surgery	30	124.8 (13.1)	---	---	---
12 months	28	102.9 (17.2)	---	-22.7 (-27.2 to -18.2)	< 0.001

Abbreviations: CI: confidence interval; SD: standard deviation. *Comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]). †: Comparison done using paired samples t-test.

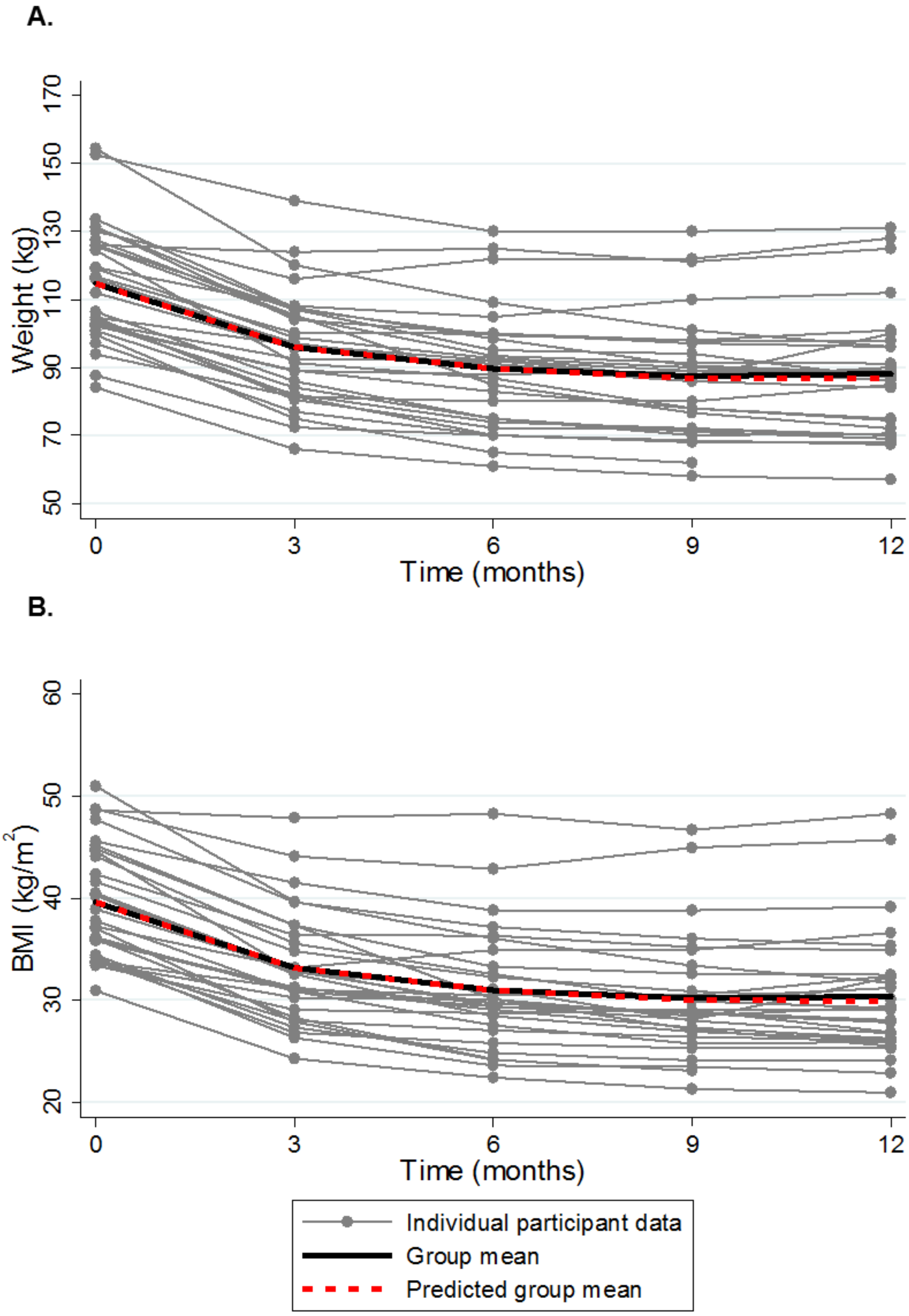

Figure 4.13. Data collected at each assessment time point for measures of (A) weight and (B) body mass index (BMI). The pre-surgery assessment time point is denoted by 0 months.

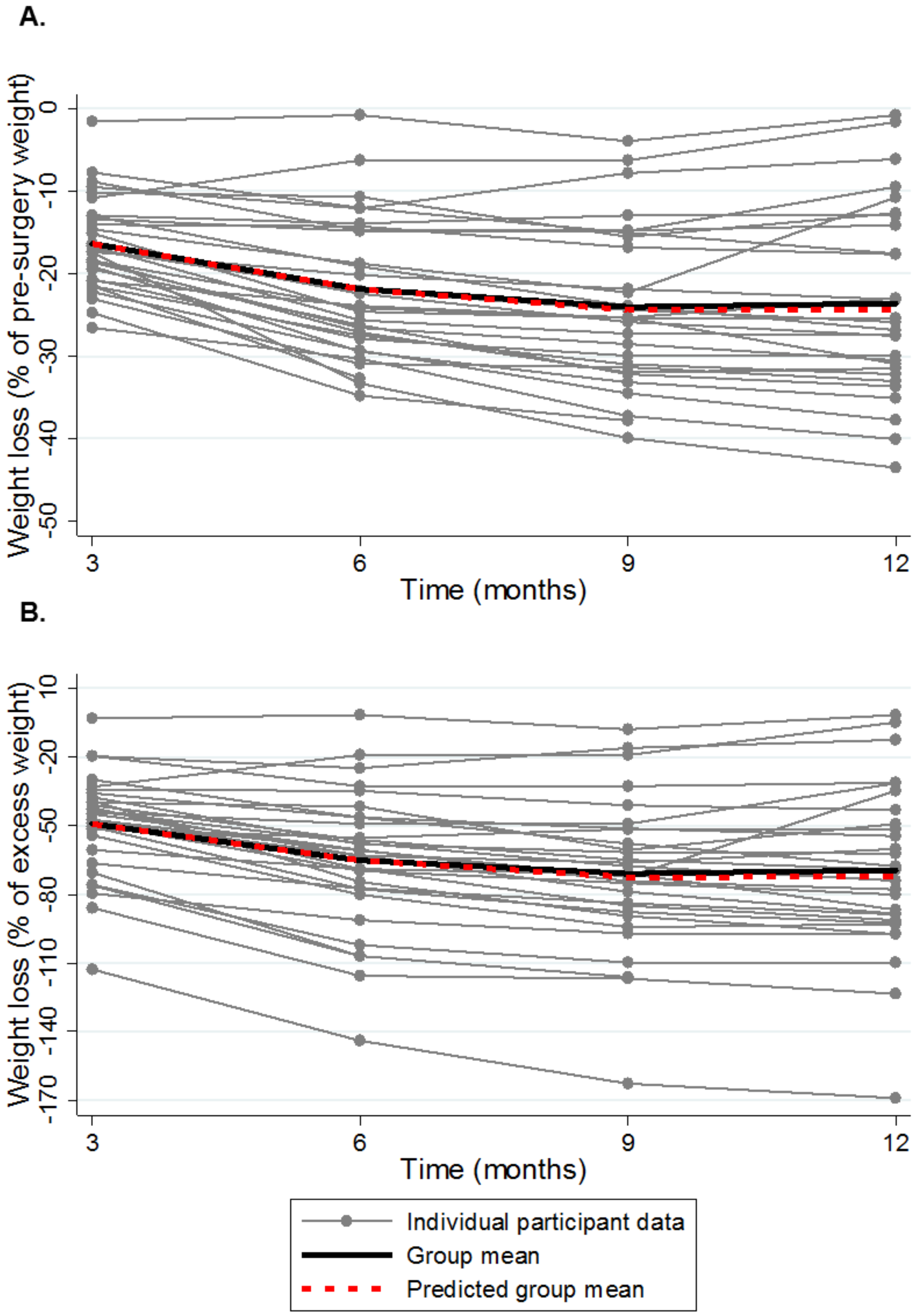

Figure 4.14. Data collected at each assessment time point for measures of (A) % of pre-surgery weight loss and (B) % of excess weight loss.

4.1.8.1 Weight-related measures according to surgery type

Table 4.12 presents data pertaining to differences, between those who underwent LSG and LAGB, in change in weight-related measures. Figures 4.15 and 4.16 present data collected at each assessment time point for weight and BMI, and weight loss expressed as the percentage of pre-surgery weight and the percentage of excess weight, respectively, with participants grouped according to surgery type. There was a greater change in all weight-related measures for those who underwent LSG when compared to those who underwent LAGB. Compared to pre-surgery measures, 12 months post-surgery, there was a mean weight reduction of 31.9 kg (95% CI, 28.2 to 35.6) following LSG and 17.3 kg (95% CI, 11.2 to 23.3) following LAGB, a mean BMI reduction of 11.1 kg/m^2 (95% CI, 9.9 to 12.4) following LSG and 5.8 kg/m^2 (95% CI, 3.7 to 7.9) following LAGB, a mean loss of 29% (95% CI, 26 to 32) of their pre-surgery weight following LSG and 13% (95% CI, 8 to 18) following LAGB, and a mean %EWL of 87% (95% CI, 77 to 97) following LSG and 33% (95% CI, 17 to 50) following LAGB. Table 4.12 and Figures 4.15 and 4.16 show that the majority of change in weight-related measures occurred in the first 3 months for both surgery types, followed by smaller changes up to 12 months post-surgery. There was a greater weight loss in those who underwent LSG, when compared to those who underwent LAGB, during the first 6 months post-surgery, and similar weight loss occurred for both surgery types between 6 and 12 months post-surgery.

Table 4.12. Change in weight-related measures according to surgery type

Assessment time point	n	Predicted Mean		Mean change from preceding time point		Difference in mean change between LSG and LAGB (95%CI)	p-value
		LSG	LAGB	LSG	LAGB		
Weight (kg)							
Pre-surgery	30	111.0	124.7	---	---	---	---
3 months	30	90.6	110.6	-20.4	-14.0	-6.4 (-10.0 to -2.7)	0.001
6 months	30	83.0	107.9	-7.6	-2.8	-4.8 (-8.5 to -1.1)	0.010
9 months	29	79.6	106.2	-3.4	-1.6	-1.8 (-5.5 to 1.9)	0.34
12 months	28	79.1	107.4	-0.6	1.2	-1.7 (-5.4 to 2.0)	0.36
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				-31.9	-17.3	-14.6 (-21.8 to -7.5)	< 0.001
Body mass index (kg/m²)							
Pre-surgery	30	38.4	42.9	---	---	---	---
3 months	30	31.3	38.1	-7.1	-4.8	-2.3 (-3.6 to -1.1)	< 0.001
6 months	30	28.7	37.2	-2.7	-0.9	-1.7 (-2.9 to -0.5)	0.007
9 months	29	27.5	36.6	-1.2	-0.5	-0.7 (-1.9 to 0.6)	0.29
12 months	28	27.3	37.1	-0.2	0.4	-0.6 (-1.9 to 0.6)	0.31
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				-11.1	-5.8	-5.3 (-7.7 to -2.9)	< 0.001
% of baseline weight loss							
3 months	30	-18	-11	-18	-11	-7 (-13 to -2)	0.013
6 months	30	-25	-13	-7	-2	-5 (-7 to -2)	<0.001
9 months	29	-28	-14	-3	-1	-2 (-4 to 1)	0.15
12 months	28	-29	-13	-1	1	-2 (-4 to 0)	0.22
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				-29	-13	-15 (-21 to -10)	< 0.001

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Assessment time point	n	Predicted Mean		Mean change from preceding time point		Difference in mean change between LSG and LAGB (95%CI)	p-value
% of excess weight loss							
3 months	30	-57	-28	-57	-28	-28 (-48 to -9)	0.003
6 months	30	-77	-33	-20	-5	-15 (-22 to -8)	< 0.001
9 months	29	-86	-36	-9	-3	-6 (-13 to 2)	0.12
12 months	28	-87	-33	-1	3	-4 (-11 to 3)	0.27
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				-87	-33	-53 (-72 to -34)	< 0.001

Abbreviations: CI: confidence interval. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point including cases missing in that time point [predicted mean]).

A.

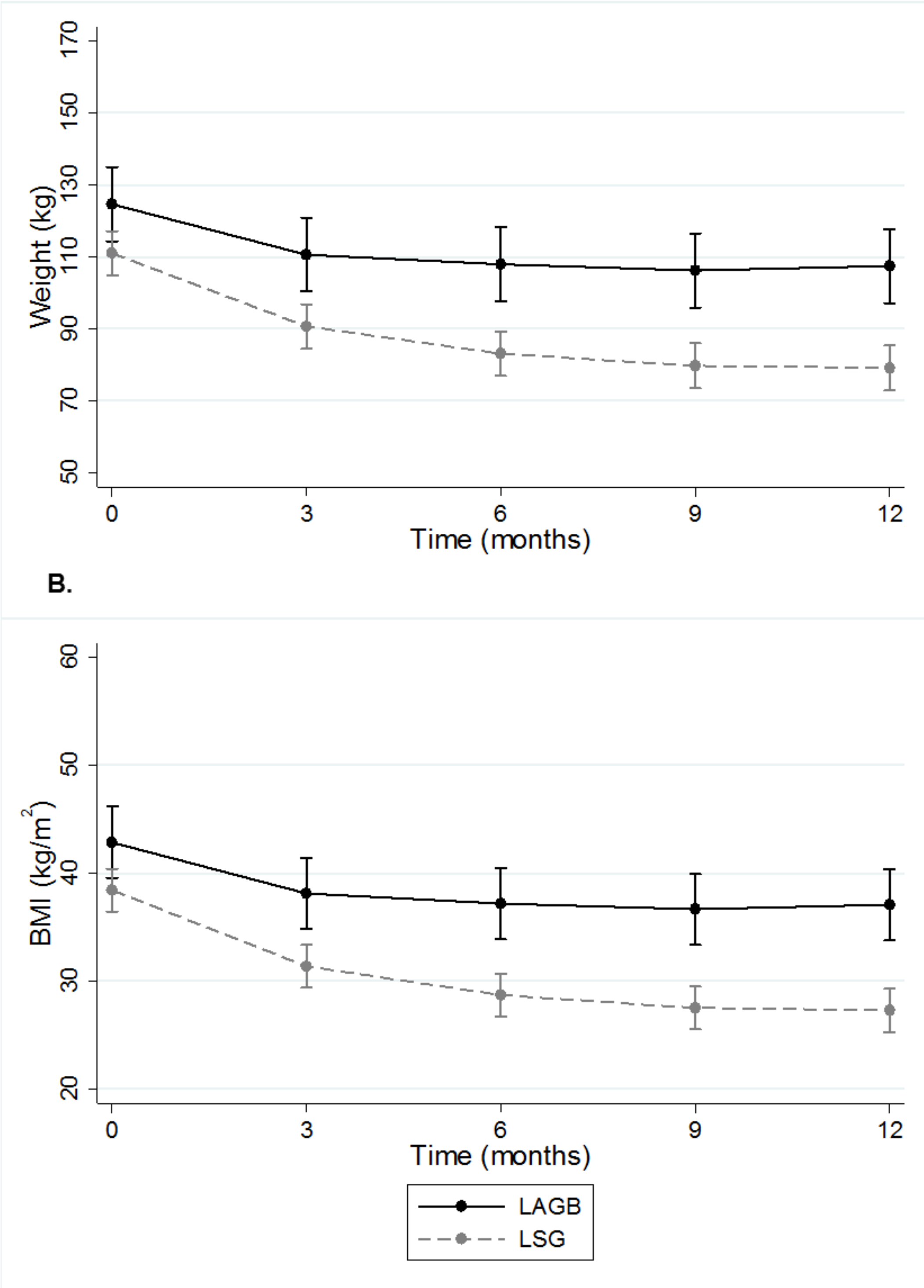

Figure 4.15. Data collected at each assessment time point for measures of (A) weight and (B) body mass index (BMI), with participants grouped according to surgery type (predicted means with 95% confidence intervals). The pre-surgery assessment time point is denoted by 0 months.

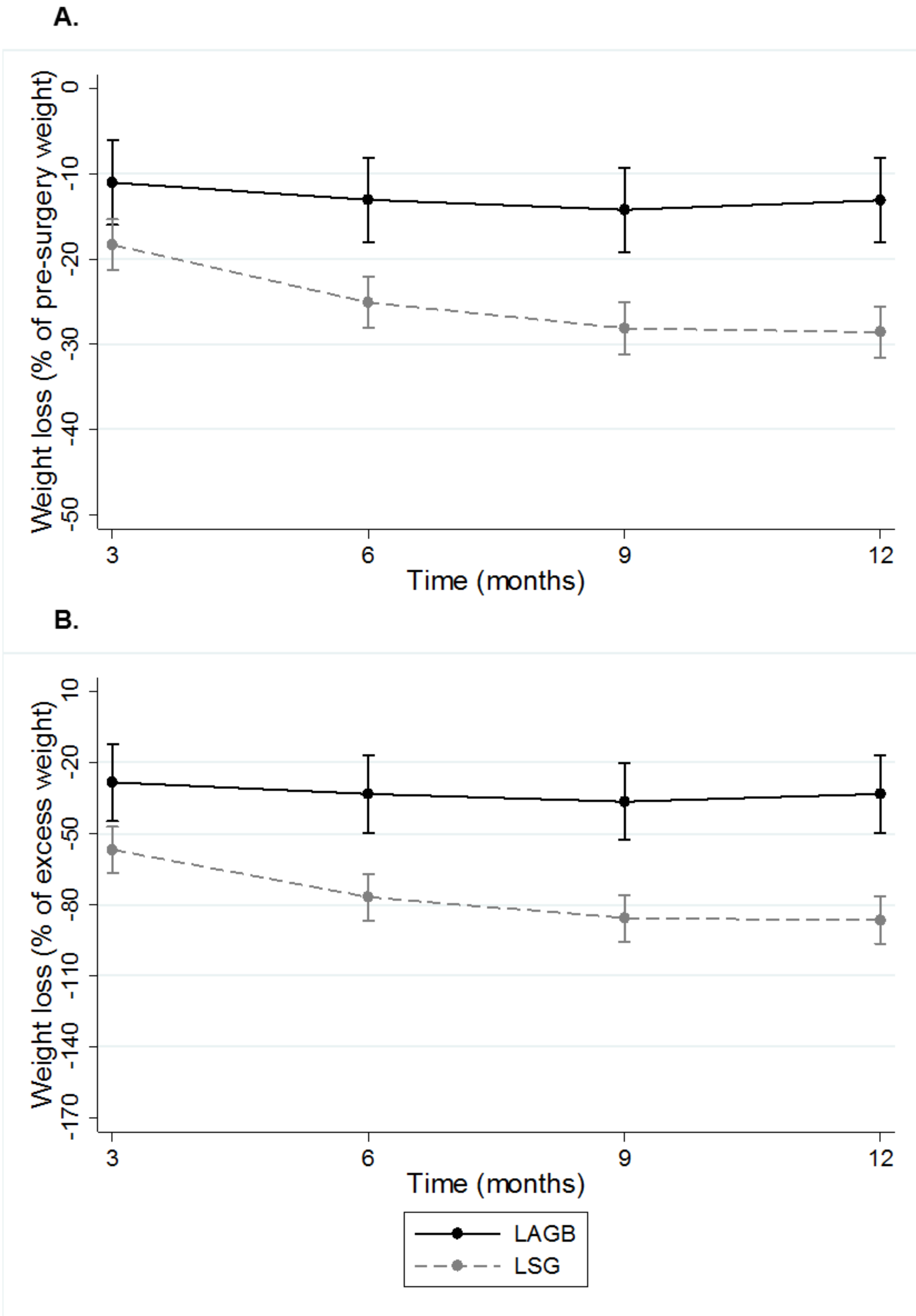

Figure 4.16. Data collected at each assessment time point for measures of (A) % of pre-surgery weight loss and (B) % of excess weight loss, with participants grouped according to surgery type (predicted means with 95% confidence intervals).

4.1.9 Obesity-related comorbid conditions

This section provides data pertaining to change in measures of obesity-related comorbid conditions collected pre-surgery and 12 months post-surgery, as well as in measures of sleep disordered breathing collected pre-surgery, and 3, 6, 9 and 12 months post-surgery in order to answer research question (iii). Table 4.13 presents data pertaining to resolution in obesity-related comorbid conditions. Both pre-surgery and 12 months post-surgery, 8 (27%) participants presented with at least one medically diagnosed obesity-related comorbid condition.

Improvement in obesity-related comorbid conditions was seen in two (25%) of the eight participants who had dyslipidaemia and three (38%) of the eight participants who had hypertension. Three (43%) of the six participants who presented with medically diagnosed obstructive sleep apnoea (OSA) made use of a continuous positive airway pressure device pre-surgery, which was discontinued by two at 12 months post-surgery. Table 4.13 shows that two (40%) of five participants presented resolution of diabetes mellitus type 2, and three (38%) of eight presented resolution of hypertension.

Table 4.14 presents data pertaining to change in sleep disordered breathing measured using the ApneaLink™. Figure 4.17 presents data collected at each assessment time point for sleep disordered breathing, expressed by the apnoea-hypopnoea index (AHI). As these data were analysed using a negative binomial model due to the right skewed distribution, change estimates are reported as incidence rate ratios (IRR), which represent the proportional rather than absolute change between assessment time points. Compared to pre-surgery measures, 12 months post-surgery, there was no change in the AHI (IRR, 0.45; 95% CI, 0.14 to 1.41).

Table 4.13. Resolution in obesity-related comorbid conditions

Obesity-related comorbid condition			p-value
Diabetes mellitus type 2			
	12 months post-surgery		
Pre-surgery	Present	Absent	
Present	3	2	
Absent	0	24	0.50
Dyslipidaemia			
	12 months post-surgery		
Pre-surgery	Present	Absent	
Present	8	0	
Absent	0	21	> 0.99
Hypertension			
	12 months post-surgery		
Pre-surgery	Present	Absent	
Present	5	3	
Absent	0	21	0.25
Obstructive sleep apnoea			
	12 months post-surgery		
Pre-surgery	Present	Absent	
Present	6	0	
Absent	0	23	> 0.99

All comparisons done using McNemar's exact test.

Table 4.14. Change in sleep disordered breathing

Assessment time point	n	Observed Median (IQR)	Predicted Mean	IRR (95%CI)	p-value
Sleep disordered breathing (apnoea-hypopnoea index [events/hour])					
Pre-surgery	20	4.5 (2.5 - 9.0)	8	---	---
3 months	17	5.0 (2.0 - 6.0)	6	0.80 (0.54 to 1.18)	0.27
6 months	11	4.0 (1.0 - 13.0)	7	1.15 (0.75 to 1.77)	0.50
9 months	12	2.5 (1.0 - 4.5)	6	0.82 (0.50 to 1.36)	0.45
12 months	10	4.0 (2.0 - 9.0)	3	0.58 (0.24 to 1.38)	0.22
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				0.45 (0.14 to 1.41)	0.17

Abbreviations: CI: confidence interval; IQR: interquartile range. The model estimates mean and proportional change in the mean (expressed by the incidence rate ratio [IRR]) relative to the preceding assessment time point. All comparisons done using negative binomial model.

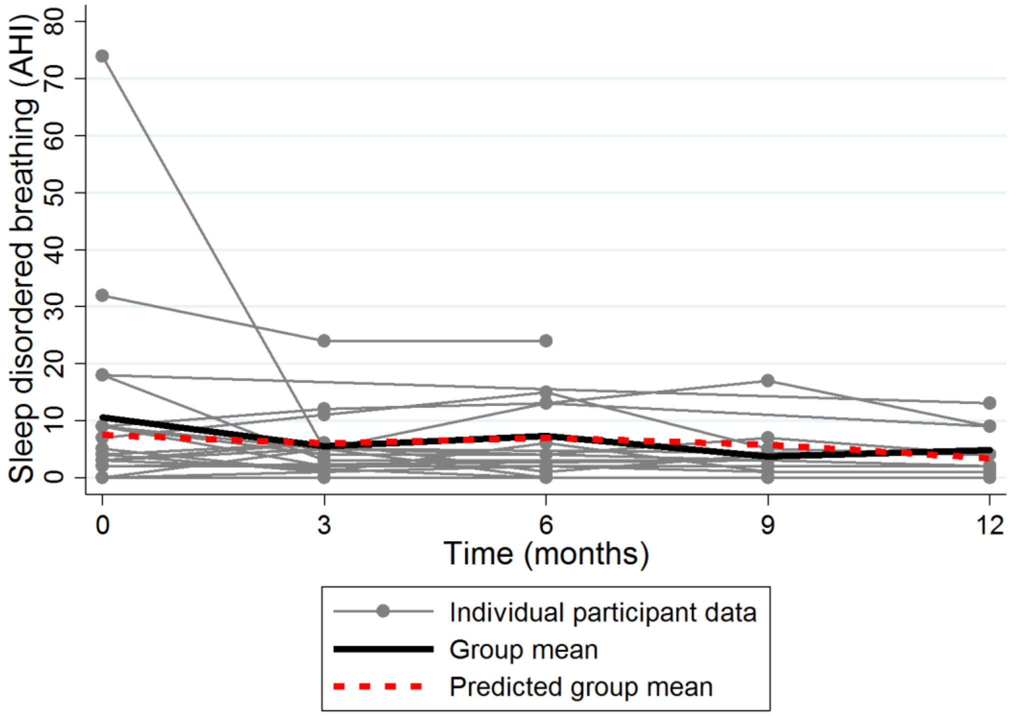

Figure 4.17. Data collected at each assessment time point for sleep disordered breathing, expressed by the apnoea-hypopnoea index (AHI). The pre-surgery assessment time point is denoted by 0 months.

4.1.10 Health-related quality of life, obesity-related quality of life and weight-related symptoms

This section provides data pertaining to change in measures of HRQoL and obesity-related quality of life and weight-related symptoms collected pre-surgery, and 3, 6, 9 and 12 months post-surgery in order to answer research question (iii).

4.1.10.1 Health-related quality of life

Table 4.15 presents data pertaining to change in physical and mental HRQoL measured using the component summaries of the Medical Outcomes Study Short Form 12 General Health Survey version 2 (SF-12v2). Figure 4.18 presents data collected at each assessment time point for physical and mental HRQoL, expressed by the scores of the component summaries of the SF-12v2, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was an increase in physical HRQoL, measured using the physical component summary (PCS) of the SF-12v2 (mean change, 12.2; 95% CI, 8.5 to 15.9). Table 4.15 and Figure 4.18(A) show that the majority of change in physical HRQoL occurred in the first 3 months, and was maintained up to 12 months post-surgery. Compared to pre-surgery measures, 12 months post-surgery, there was no change in mental HRQoL measured using the mental component summary (MCS) of the SF-12v2 (mean change, 3.4; 95% CI, -0.9 to 7.6). Table 4.15 and Figure 4.18(B) show that there was a significant increase in mental HRQoL between the pre-surgery assessment and the 3-month post-surgery assessment (mean change, 5.1; 95% CI, 2.4 to 7.8), which was not maintained up to 12 months post-surgery. Of note, at 12 months, the change in both PCS and MCS scores exceeded the minimal clinically important difference reported for these measures of 3 to 5 points (568, 569).

Table 4.15. Change in physical and mental health-related quality of life

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Physical health-related quality of life (PCS score of the SF-12v2)					
Pre-surgery	30	43.2 (7.9)	43.2	---	---
3 months	30	52.5 (7.0)	52.5	9.3 (6.5 to 12.1)	< 0.001
6 months	29	51.7 (9.8)	51.7	-0.8 (-3.6 to 2.1)	0.59
9 months	29	54.3 (5.9)	54.3	2.6 (-0.3 to 5.4)	0.07
12 months	28	55.2 (6.4)	55.4	1.1 (-1.8 to 4.0)	0.47
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				12.2 (8.5 to 15.9)	< 0.001
Mental health-related quality of life (MCS score of the SF-12v2)					
Pre-surgery	30	47.1 (9.9)	47.1	---	---
3 months	30	52.2 (8.2)	52.2	5.1 (2.4 to 7.8)	< 0.001
6 months	29	51.1 (9.4)	51.1	-1.1 (-3.8 to 1.6)	0.42
9 months	29	50.4 (10.0)	50.4	-0.7 (-3.4 to 2.0)	0.63
12 months	28	50.8 (9.5)	50.5	0.0 (-2.7 to 2.8)	0.98
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				3.4 (-1 to 7.6)	0.11

Abbreviations: CI: confidence interval; MCS: mental component summary; PCS: physical component summery; SD: standard deviation; SF-12v2: Medical Outcomes Study Short Form 12 General Health Survey version 2. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]).

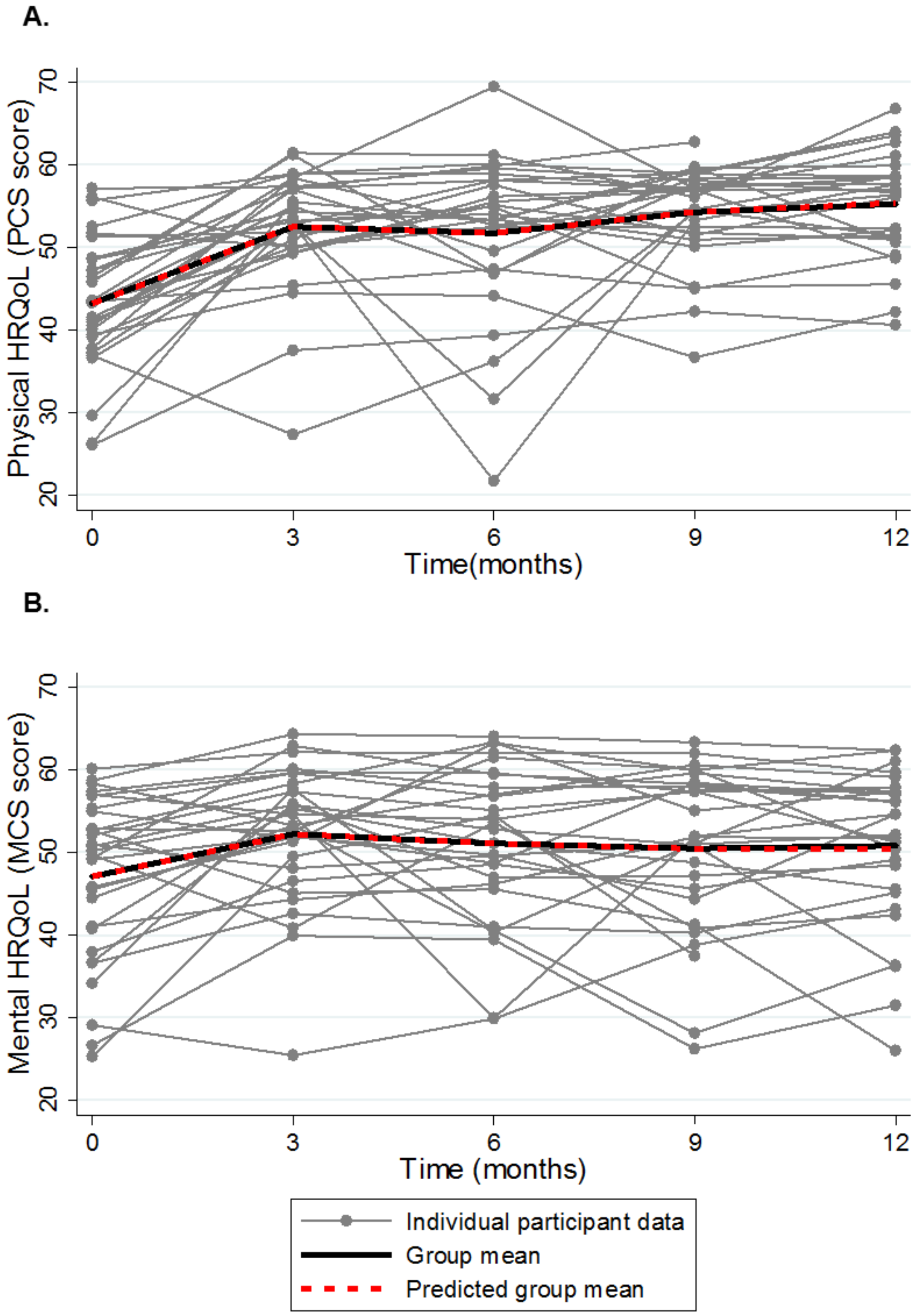

Figure 4.18. Data collected at each assessment time point for (A) physical health-related quality of life (HRQoL), measured using the physical component summary (PCS) of the Medical Outcomes Study Short Form 12 General Health Survey version 2 (SF-12v2) and (B) mental HRQoL, measured using the mental component summary (MCS) of the SF-12v2. The pre-surgery assessment time point is denoted by 0 months.

4.1.10.2 Obesity-related quality of life and weight-related symptoms

Obesity-related quality of life was measured with two instruments: the Impact of Weight on Quality of Life Questionnaire (IWQOL-Lite) and the Obesity and Weight-loss Quality-of-life Instrument (OWLQOL), while weight-related symptoms were measured using the Weight-related Symptoms Measure (WRSM). Table 4.16 presents data pertaining to change in obesity-related quality of life, measured using the IWQOL-Lite. Figure 4.19 presents data collected at each assessment time point for obesity-related quality of life, expressed by the total score of the IWQOL-Lite, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was an improvement in obesity-related quality of life measured using the total and domains' scores of the IWQOL-Lite (total: mean change, 34.1; 95% CI, 28.1 to 40.0; physical function domain: mean change, 37.1; 95% CI, 30.3 to 44.0; self-esteem domain: mean change, 42.8; 95% CI, 33.0 to 52.6; sexual life domain: mean change, 27.6; 95% CI, 17.2 to 38.1; public distress domain: mean change, 29.1; 95% CI, 21.1 to 37.1; work domain: mean change, 22.7; 95% CI, 17.0 to 28.5). Table 4.16 and Figure 4.19 show that the majority of change in obesity-related quality of life occurred in the first 3 months, with the total score demonstrating smaller changes at 6 and 9 months, which were maintained up to 12 months post-surgery. Of note, at 12 months, the change in the total score of the IWQOL-Lite exceeded the minimal clinically important difference reported for this measure of 12 points (574).

Table 4.16. Change in obesity-related quality of life

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Total score of the IWQOL_Lite					
Pre-surgery	30	56.3 (15.7)	56.3	---	---
3 months	30	79.5 (19.8)	79.5	23.3 (19.9 to 26.7)	< 0.001
6 months	29	84.4 (17.7)	84.5	5.0 (1.5 to 8.4)	0.005
9 months	29	89.1 (13.0)	89.2	4.7 (1.2 to 8.2)	0.008
12 months	28	90.1 (12.8)	90.3	1.1 (-2.4 to 4.6)	0.54
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				34.1 (28.1 to 40.0)	< 0.001
Physical function domain score of the IWQOL_Lite					
Pre-surgery	30	54.5 (19.4)	54.5	---	---
3 months	30	84.1 (21.3)	84.1	29.5 (25.5 to 33.6)	< 0.001
6 months	29	87.5 (14.6)	87.9	3.8 (-0.4 to 7.9)	0.07
9 months	29	90.6 (12.2)	91.0	3.0 (-1.1 to 7.2)	0.15
12 months	28	91.2 (12.5)	91.7	0.8 (-3.4 to 5.0)	0.72
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				37.1 (30.3 to 44.0)	< 0.001
Self-esteem domain score of the IWQOL_Lite					
Pre-surgery	30	41.7 (23.8)	41.7	---	---
3 months	30	68.2 (23.9)	68.2	26.5 (20.3 to 32.8)	< 0.001
6 months	29	76.5 (24.4)	76.6	8.4 (2.0 to 14.8)	0.010
9 months	29	84.5 (17.2)	84.6	8.0 (1.6 to 14.3)	0.015
12 months	28	84.4 (16.9)	84.4	-0.1 (-6.6 to 6.4)	0.96
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				42.8 (33.0 to 52.6)	< 0.001

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Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Sexual life domain score of the IWQOL_Lite					
Pre-surgery	30	61.5 (27.5)	61.5	---	---
3 months	30	74.4 (26.8)	74.4	12.9 (6.6 to 19.3)	< 0.001
6 months	29	80.4 (25.5)	79.8	5.4 (-1.0 to 11.8)	0.09
9 months	29	86.9 (23.3)	86.4	6.6 (0.2 to 13.1)	0.043
12 months	28	89.1 (18.2)	89.1	2.7 (-3.9 to 9.2)	0.42
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				27.6 (17.2 to 38.1)	< 0.001
Public distress domain score of the IWQOL_Lite					
Pre-surgery	30	65.0 (21.3)	65.0	---	---
3 months	30	83.3 (20.9)	83.3	18.3 (13.5 to 23.2)	< 0.001
6 months	29	87.8 (23.5)	88.0	4.7 (-0.2 to 9.7)	0.06
9 months	29	90.9 (15.9)	91.1	3.0 (-1.9 to 8.0)	0.23
12 months	28	93.8 (11.1)	94.1	3.1 (-2.0 to 8.1)	0.23
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				29.1 (21.1 to 37.1)	< 0.001
Work domain score of the IWQOL_Lite					
Pre-surgery	30	70.4 (20.7)	70.4	---	---
3 months	30	87.3 (20.1)	87.3	16.9 (13.8 to 19.9)	< 0.001
6 months	29	89.4 (20.1)	89.3	2.0 (-1.2 to 5.1)	0.21
9 months	29	93.3 (15.0)	93.2	3.9 (0.8 to 7.0)	0.014
12 months	28	93.1 (15.4)	93.1	-0.0 (-3.2 to 3.2)	0.99
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				22.7 (17.0 to 28.5)	< 0.001

Abbreviations: CI: confidence interval; IWQOL-Lite: short version of the Impact of Weight on Quality of Life Questionnaire; SD: standard deviation. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]).

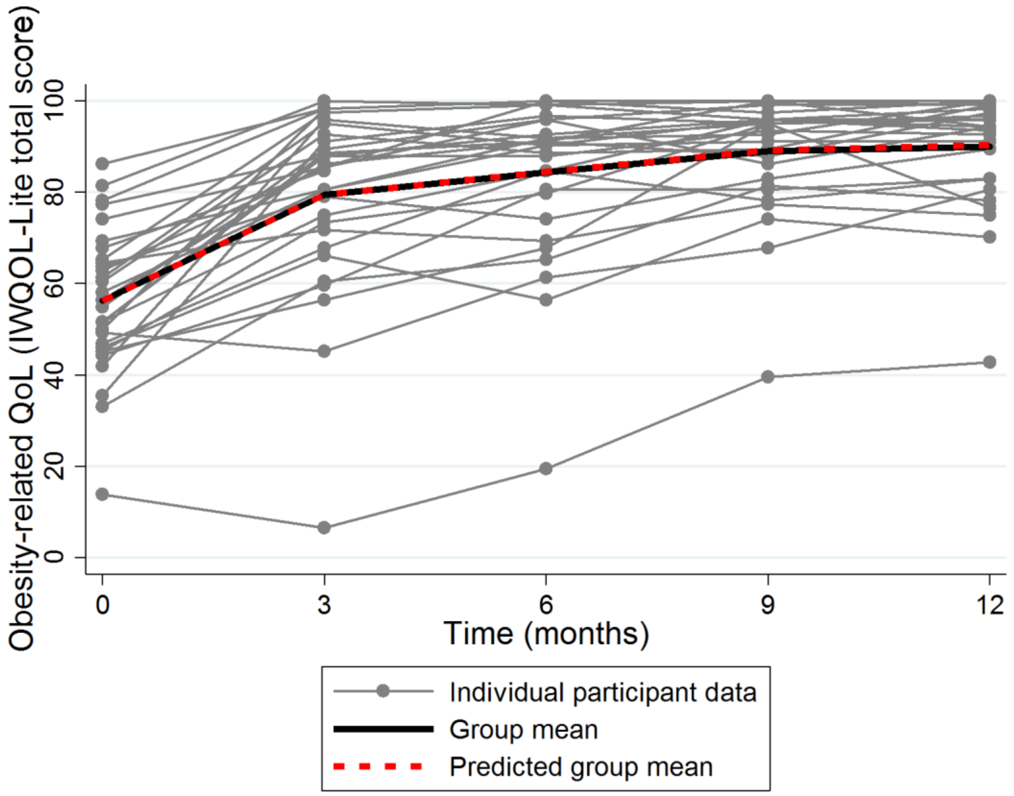

Figure 4.19. Data collected at each assessment time point for obesity-related quality of life (QoL), expressed by the total score of the short version of the Impact of Weight on Quality of Life Questionnaire (IWQOL-Lite). The pre-surgery assessment time point is denoted by 0 months.

Table 4.17 presents data pertaining to change in obesity-related quality of life and weight-related symptoms, measured using the OWLQOL and WRSM, respectively. Figure 4.20 presents data collected at each assessment time point for obesity-related quality of life, expressed by the OWLQOL score, and weight-related symptoms, expressed by the WRSM score, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was an improvement in obesity-related quality of life (mean change, 42.8; 95% CI, 34.0 to 51.5) and a reduction in weight-related symptoms (mean change, -23.7; 95% CI, -29.6 to -17.8). Table 4.17 and Figure 4.20 show that the majority of change in obesity-related quality of life and in weight-related symptoms occurred in the first 3 months, with smaller changes up to 6 months, which were maintained up to 12 months post-surgery.

Table 4.17. Change in obesity-related quality of life and weight-related symptoms

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Obesity-related quality of life (OWLQOL score)					
Pre-surgery	30	38.5 (17.0)	38.5	---	---
3 months	30	68.8 (23.8)	68.8	30.3 (24.8 to 35.8)	< 0.001
6 months	29	76.4 (21.0)	76.6	7.8 (2.2 to 13.4)	0.006
9 months	29	80.9 (17.7)	81.0	4.5 (-1.1 to 10.1)	0.11
12 months	28	81.3 (19.0)	81.2	0.2 (-5.5 to 5.9)	0.95
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				42.8 (34.0 to 51.5)	< 0.001
Weight-related symptoms (WRSM score)					
Pre-surgery	30	33.4 (16.8)	33.4	---	---
3 months	30	16.0 (15.0)	16.0	-17.4 (-21.0 to -13.7)	< 0.001
6 months	29	11.4 (11.2)	11.8	-4.2 (-7.9 to -0.5)	0.026
9 months	29	11.6 (12.4)	11.8	-0.0 (-3.7 to 3.7)	0.99
12 months	28	9.6 (10.1)	9.7	-2.1 (-5.9 to 1.6)	0.26
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-23.7 (-29.6 to -17.8)	< 0.001

Abbreviations: CI: confidence interval; OWLQOL: Obesity and Weight-loss Quality-of-life Instrument; SD: standard deviation; WRSM: Weight-related Symptoms Measure. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]).

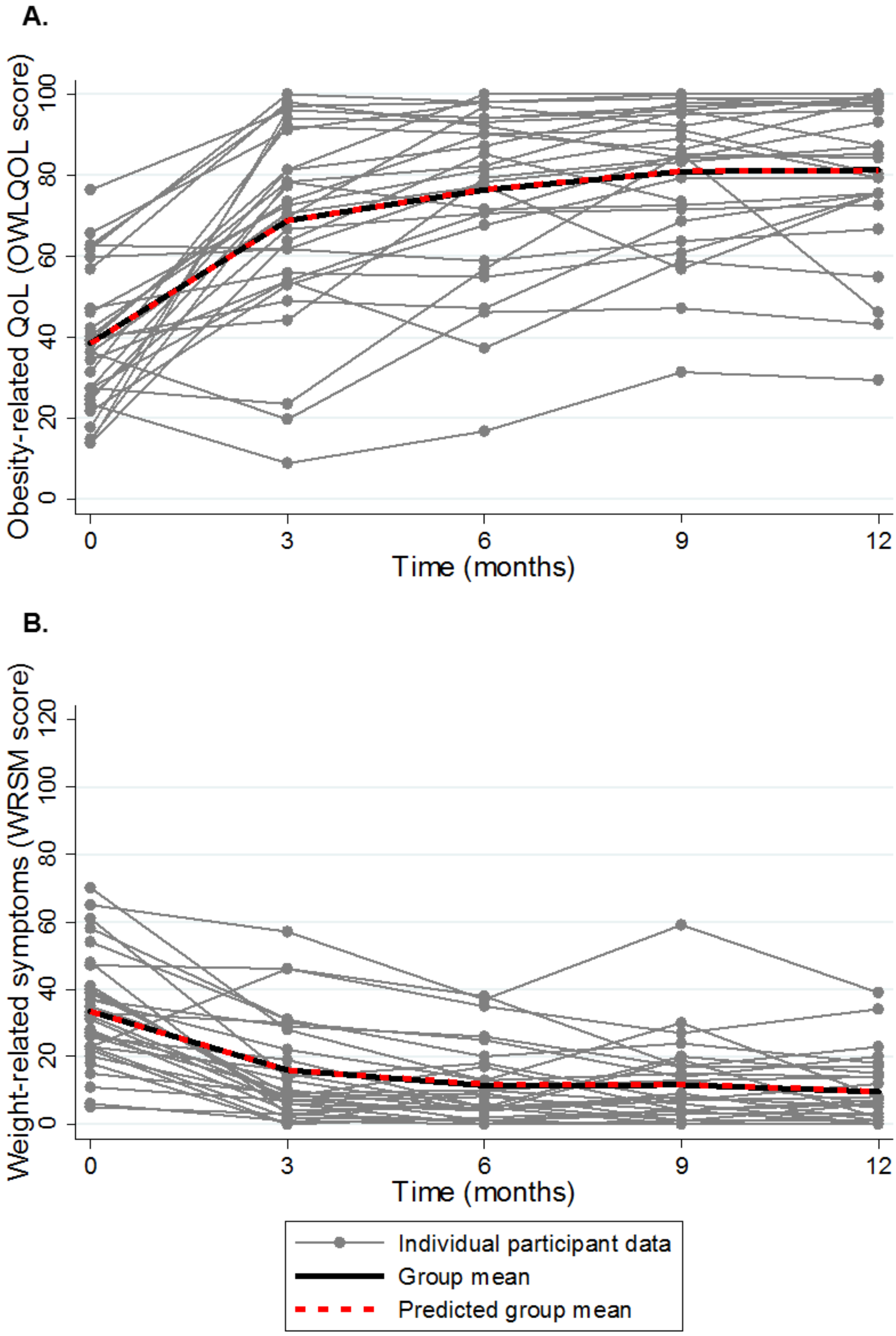

Figure 4.20. Data collected at each assessment time point for (A) obesity-related quality of life (QoL), expressed by the score of the OWLQOL, and (B) weight-related symptoms, expressed by the score of the WRSM. The pre-surgery assessment time point is denoted by 0 months.

4.1.11 Mental health

This section provides data pertaining to change in measures of symptoms of depression, anxiety and stress collected pre-surgery, and 3, 6, 9 and 12 months post-surgery in order to answer research question (iii). Symptoms of depression were measured using the Beck Depression Inventory (BDI), and symptoms of depression, anxiety and stress were measured using the Depression Anxiety Stress Scales (DASS-21). Table 4.18 presents data pertaining to change in symptoms of depression measured using the BDI. Figure 4.21 presents data collected at each assessment time point for symptoms of depression, expressed by the BDI score, with the addition of plots for individual participants to depict individual variability. Compared to pre-surgery measures, 12 months post-surgery, there was a reduction in symptoms of depression (mean change, -7.7; 95% CI, -10.4 to -5.1). Table 4.18 and Figure 4.21 show that the majority of change in symptoms of depression occurred in the first 3 months, and was maintained up to 12 months post-surgery. Of note, at 12 months, the change in the BDI score exceeded the minimal clinically important difference reported for this measure (i.e. change > 17.5% of the pre-surgery BDI score) (593).

Table 4.19 presents data pertaining to change in symptoms of depression, anxiety and stress, measured using the subscales of the DASS-21. Figures 4.22 to 4.24 present data collected at each assessment time point for symptoms of depression, anxiety, and stress, measured using the subscales of the DASS-21, with the addition of plots for individual participants to depict individual variability. As these data were analysed using a negative binomial model due to the right skewed distribution, change estimates are reported as IRRs. Compared to pre-surgery measures, 12 months post-surgery, there was a 44% reduction in symptoms of depression, 54% reduction in symptoms of anxiety, and 39% reduction in symptoms of stress. Table 4.19 and Figures 4.22 to 4.24 show that the majority of change in symptoms of depression, anxiety and stress occurred in the first 3 months, and was maintained up to 12 months post-surgery.

Table 4.18. Change in symptoms of depression

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Symptoms of depression (Beck Depression Inventory score)					
Pre-surgery	30	12.4 (7.5)	12.4	---	---
3 months	30	6.6 (5.9)	6.6	-5.8 (-7.3 to -4.2)	< 0.001
6 months	29	6.2 (6.7)	6.2	-0.4 (-2.0 to 1.2)	0.64
9 months	29	5.0 (6.0)	5.0	-1.3 (-2.9 to 0.3)	0.11
12 months	28	4.6 (5.4)	4.6	-0.3 (-1.9 to 1.3)	0.69
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-7.7 (-10.4 to -5.1)	< 0.001

Abbreviations: CI: confidence interval; SD: standard deviation. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]).

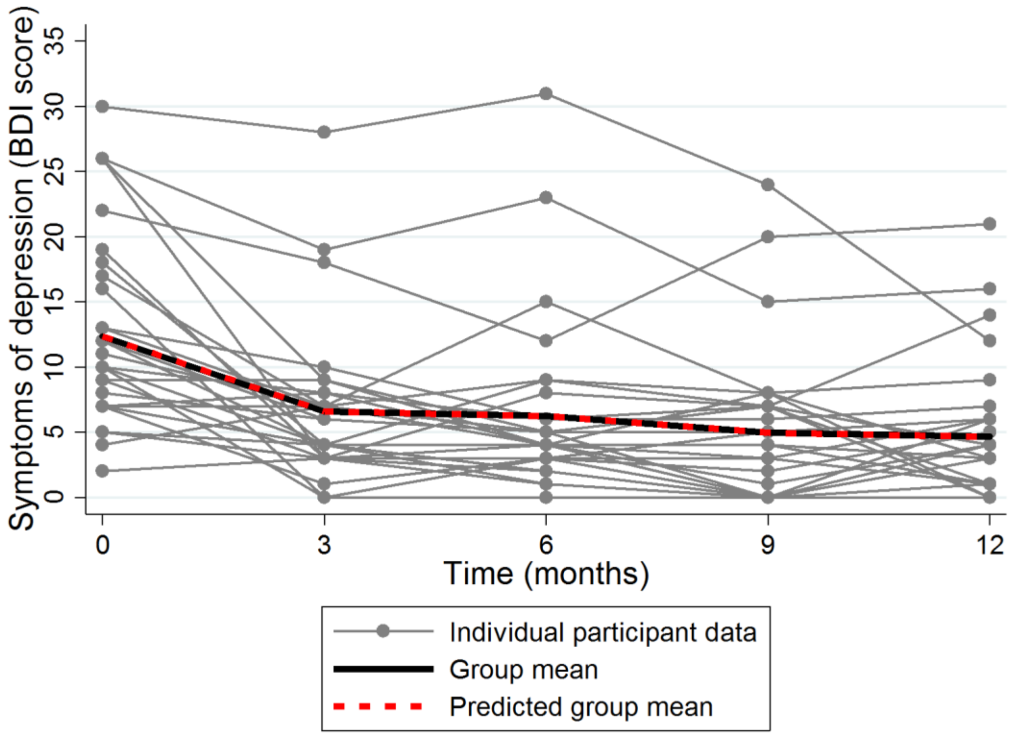

Figure 4.21. Data collected at each assessment time point for symptoms of depression, expressed by the score of the Beck Depression Inventory (BDI). The pre-surgery assessment time point is denoted by 0 months.

Table 4.19. Change in symptoms of depression, anxiety and stress

Assessment time point	n	Observed Median (IQR)	Predicted Mean	IRR (95%CI)	p-value
Symptoms of depression (depression subscale of the DASS-21)					
Pre-surgery	30	3.0 (0 - 7.0)	4.9	---	---
3 months	30	1.0 (0 - 3.0)	2.3	0.47 (0.33 to 0.68)	< 0.001
6 months	29	2.0 (0 - 4.0)	3.2	1.38 (0.96 to 1.97)	0.07
9 months	29	1.0 (0 - 4.0)	2.9	0.90 (0.64 to 1.25)	0.53
12 months	28	1.0 (0 - 4.0)	2.8	0.95 (0.67 to 1.35)	0.79
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				0.56 (0.32 to 0.97)	0.040
Symptoms of anxiety (anxiety subscale of the DASS-21)					
Pre-surgery	30	3.0 (1.0 - 6.0)	3.6	---	---
3 months	30	1.0 (0 - 2.0)	1.7	0.45 (0.32 to 0.65)	< 0.001
6 months	29	1.0 (0 - 2.0)	1.8	1.05 (0.72 to 1.54)	0.78
9 months	29	1.0 (0 - 2.0)	1.7	0.95 (0.65 to 1.47)	0.81
12 months	28	1.0 (0 - 2.0)	1.7	0.99 (0.67 to 1.47)	0.99
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				0.46 (0.26 to 0.79)	0.006
Symptoms of stress (stress subscale of the DASS-21)					
Pre-surgery	30	6.0 (3.0 - 11.0)	6.8	---	---
3 months	30	5.0 (1.0 - 7.0	4.6	0.67 (0.52 to 0.85)	0.001
6 months	29	4.0 (1.0 - 6.0)	4.6	1.0 (0.77 to 1.30)	0.97
9 months	29	2.0 (1.0 - 6.0)	4.3	0.94 (0.71 to 1.23)	0.65
12 months	28	4.0 (1.0 - 6.5)	4.2	0.96 (0.73 to 1.27)	0.81
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				0.61 (0.41 to 0.91)	0.017

Abbreviations: CI: confidence interval; DASS-21: Depression Anxiety Stress Scales; IQR: interquartile range. The model estimates mean and proportional change in the mean (expressed by the incidence rate ratio [IRR]) relative to the preceding assessment time point. All comparisons done using negative binomial model.

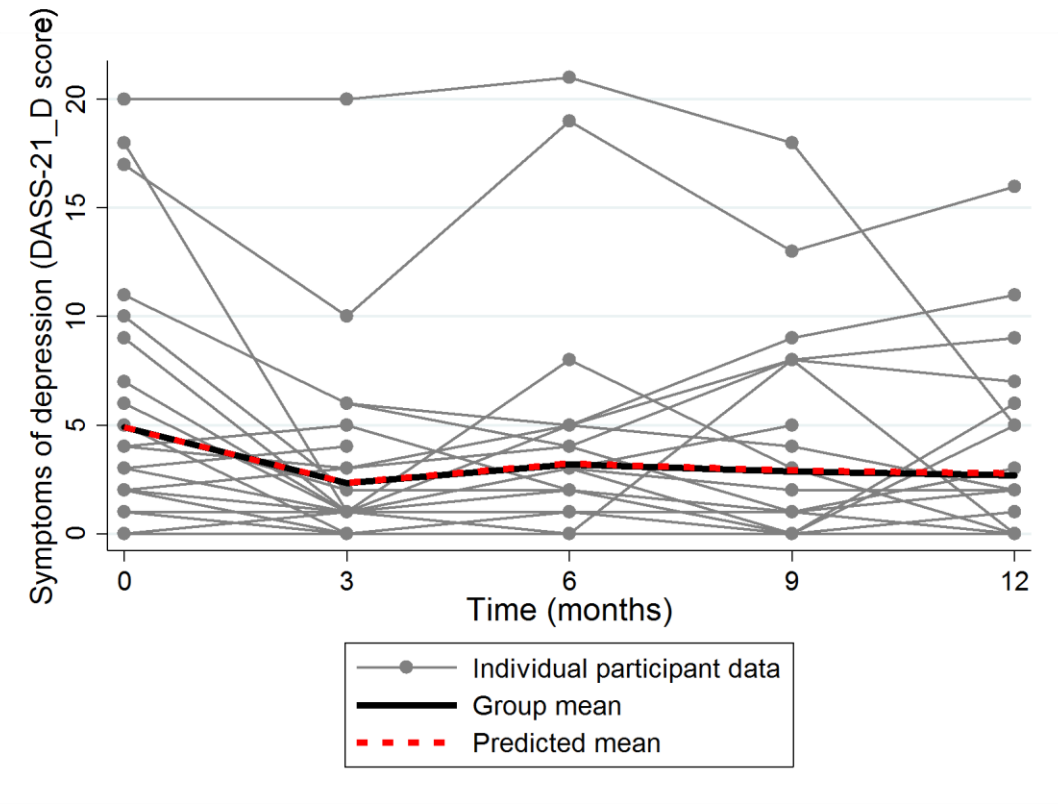

Figure 4.22. Data collected at each assessment time point for symptoms of depression, expressed by the score of the depression subscale of the Depression Anxiety Stress Scales (DASS-21_D). The pre-surgery assessment time point is denoted by 0 months.

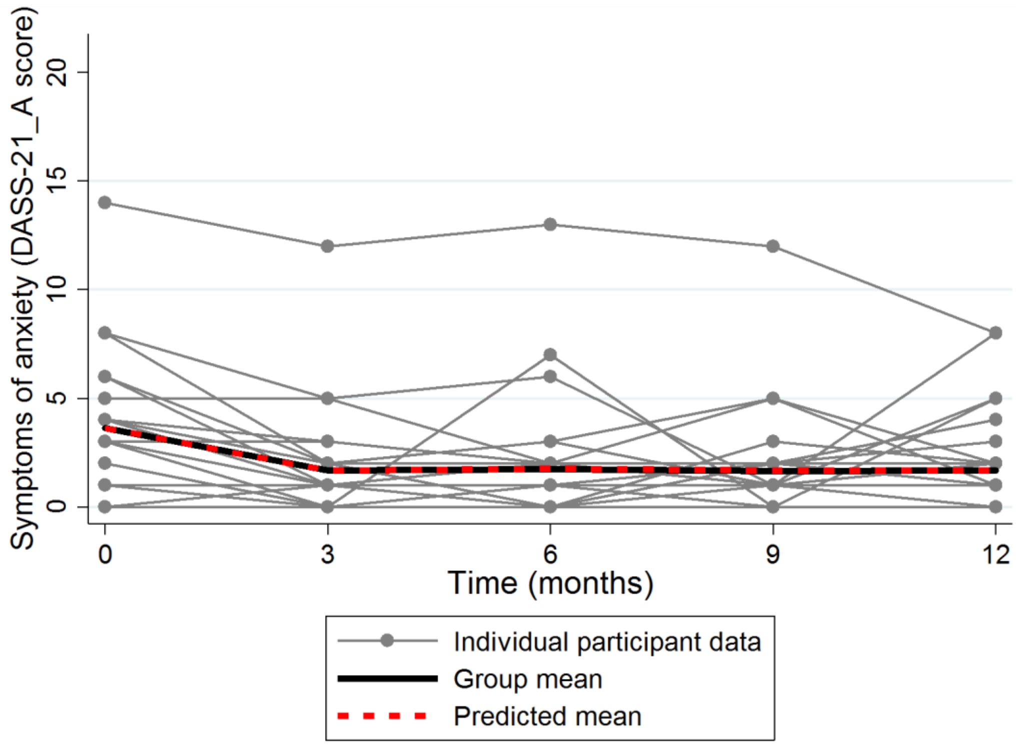

Figure 4.23. Data collected at each assessment time point for symptoms of anxiety, expressed by the score of the anxiety subscale of the Depression Anxiety Stress Scales (DASS-21_A). The pre-surgery assessment time point is denoted by 0 months.

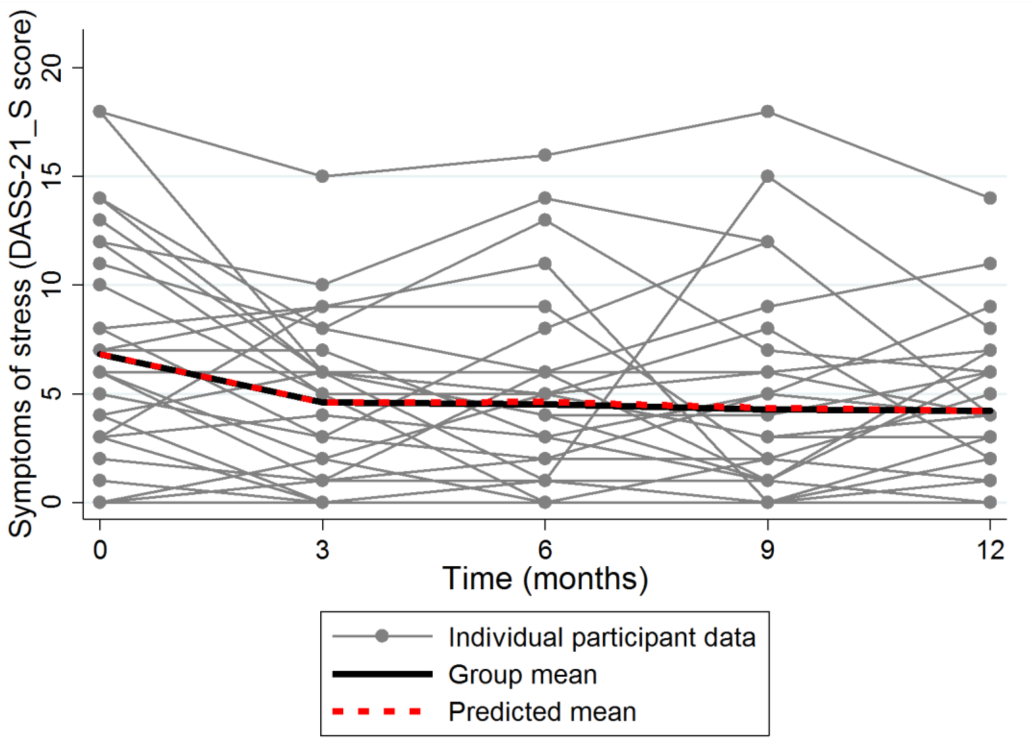

Figure 4.24. Data collected at each assessment time point for symptoms of stress, expressed by the score of the stress subscale of the Depression Anxiety Stress Scales (DASS-21_S). The pre-surgery assessment time point is denoted by 0 months.

4.2 Discussion

This study is the first to collect detailed measures of PA and SB both pre-surgery and every 3 months up to 12 months post-surgery in a group of adults who underwent restrictive bariatric surgery. These data demonstrated that, when compared to pre-surgery measures, there were no changes in measures of PA and SB in the first 12 months post-surgery. This occurred despite the fact that participants demonstrated large and significant reductions in weight-related measures that were consistent with the weight loss expected and previously described following LAGB and LSG (131-135). At all assessment time points, participants spent over 70% of their waking hours in SB, which was mostly accumulated in prolonged uninterrupted bouts ≥ 30 minutes, and only 5% of their waking hours in MVPA, which was mostly accumulated in very short bouts < 10 minutes. Additionally, the data showed that the little time participants spent in PA was mostly accumulated in short bouts of light intensity PA. Consistent with these findings was the lack of change in cardiovascular fitness. The lack of change in measures of PA, SB and cardiovascular fitness also occurred despite a significant improvement in participants' self-efficacy to exercise. Further, this study collected data pertaining to changes in body composition, measured using DXA. These data showed that the substantial weight loss achieved post-surgery was accompanied by an expected and desirable reduction in FM, as well as by an undesirable reduction in FFM. For those outcomes in which surgery produced a significant effect, the majority of change was observed in the first 3 months, with less, if any change between 6 and 12 months post-surgery.

Data collected in this study revealed no change in measures of PA and SB collected over the first 12 months post-surgery. Specifically, pre-surgery and at all assessment time points post-surgery, participants spent most (> 70% or > 638 minutes/day) of their waking hours in SB, little (around 20% or 209 minutes/day) of their waking hours in light intensity PA and almost none (around 5% or 54 minutes/day) of their waking hours in MVPA. There was also no change in participants' daily step count. The persistent minimal participation in MVPA is consistent with the lack of change in cardiovascular fitness following surgery shown in this study, and by others (83, 84). That is, following surgery, in order for participants to demonstrate a reduction in heart rate at a given work rate, and improve their performance on the PWC-170, the contribution stroke volume makes to cardiac output at similar work rates would need to increase. For such changes to occur following bariatric surgery, participants would need to have increased their participation in purposeful exercise, which would, in turn, have been captured as an increased participation in MVPA and/or daily step count (594). The lack of change in measures of PA and SB is generally consistent with earlier research of people at 6 and 9 months following gastric bypass (5, 8, 9). The present study has extended the current knowledge by providing robust data, collected using two state-of-the-art devices, over multiple time points during the first 12 months following restrictive bariatric surgery, which demonstrates that despite substantial weight loss, and low prevalence of obesity-related comorbid conditions, restrictive bariatric surgery did not change participation in PA and SB. There is, however, previous work arising from a large multicentre study of people who underwent different types of bariatric surgery (mostly gastric bypass) which reported small but significant favourable changes in time spent in SB and MVPA at 12 months post-surgery, measured using the SAM (6, 7). The contrasting findings between this earlier work and the present study could be explained by possible differences regarding advice to increase participation in PA between the different centres, which was not recorded or controlled for in these studies.

Findings from a previous study of people who underwent bariatric surgery (RYGB = 214, LAGB = 67, other = 29) have shown that, at 12 months post-surgery, a 10% greater weight loss was independently associated with a significantly higher increase in min/week during which high cadence walking was recorded, but not number of steps/day or active min/day, adjusted for surgery type (21 min/week; $p = 0.01$; no CIs provided) (6). The only statistically significant association found in the present study was between less steps/day with more weight loss. This finding, and the lack of association of any other measure of PA and SB with weight loss or type of surgery may be a result of the small sample size available for analysis and the small and nonsignificant change in measures of PA and SB, therefore definitive conclusions of association between weight loss and measures of PA and SB cannot be drawn from these results.

This study is the first to demonstrate that, when compared to pre-surgery measures, the way SB and MVPA were accumulated was similar at all post-surgery assessment time points. At all assessment time points, most of the time participants spent in SB (≥ 78%) was accumulated in uninterrupted bouts of ≥ 10 minutes and over 50% of the time participants spent in SB was accumulated in uninterrupted bouts ≥ 30 minutes. This finding is of importance, as SB, especially that which is accumulated in prolonged uninterrupted periods, has been associated with poorer metabolic health (53, 439, 488). This association may be explained by the skeletal muscle's impaired ability to metabolise triglycerides and glucose caused by a reduction in skeletal muscle lipoprotein lipase activity that occurs in response to prolonged periods of SB (70, 595, 596). This reduction in skeletal muscle lipoprotein lipase activity contributes to increased cardiovascular risk by increasing plasma triglycerides and glucose levels, and inducing oxidative stress and systemic inflammation. The findings from the present study also showed that, at all assessment time points, the little time participants spent in MVPA was mostly (> 80%) accumulated in short bouts of < 10 minutes. This finding is important since the reduction in cardiometabolic risk associated with MVPA is likely to be dependent on prolonged exposure to MVPA, which results in improvements in flow-mediated endothelial function (50). Although there are no data to show the minimum bout duration of MVPA needed to condition the endothelium, current international guidelines pertaining to the amount of MVPA needed to produce health benefits states that MVPA should be accumulated in bouts of at least 10 minutes (50). These data supports findings from previous studies that reported the majority of people, both pre- and post-bariatric surgery, do not engage in sufficient bout-related MVPA in order to meet international guidelines for the development and maintenance of health (5-9).

When compared to pre-surgery measures, there was a significant improvement in self-efficacy to exercise measured at 12 months post-surgery. The lack of change in measures of PA and SB was somewhat surprising given this significant improvement in self-efficacy to exercise, which has been recognised as an important determinant of change in PA behaviour (74). This suggests that post-surgery factors other than participation in PA, such as greater ease of movement due to a reduction in physical limitations, led to participants perceiving they were more able to engage in PA or exercise. The fact that the improvement in self-efficacy to exercise found in the present study did not translate into actual change in PA behaviour supports the concept of PA behaviour being determined by multiple factors (74, 597), and suggests that there might be other factors relevant to PA behaviour that were not changed post-surgery and need to be addressed in order to optimise post-surgery participation in PA.

Regarding changes in measures of sleep quality and daytime sleepiness, the current study demonstrated that when compared to pre-surgery measures, there were significant improvements over the first 12 months post-surgery. These improvements appeared to follow the same pattern of change seen for weight-related measures, and at 12 months post-surgery, participants presented good sleep quality (PSQI score < 5) and no symptoms of excessive daytime sleepiness (ESS score < 10). Although the magnitude of change in measures of sleep quality and daytime sleepiness found in this study is in accordance to previous reports (93, 95, 96, 368), findings from the present study indicated that improved sleep quality and daytime sleepiness do not seem to result in enhanced participation in PA and SB.

Regarding changes in body composition and BMD, this study demonstrated that when compared to pre-surgery measures, there were significant reductions in FM and FFM, as well as in regional measures of BMD collected at 12 months post-surgery. These data are important and novel as to date, research that has explored measures of body composition following restrictive bariatric surgery have mostly used measurement methods known to have considerable error (i.e. bioelectrical impedance analysis) and those which have used DXA have focused exclusively on people who underwent LAGB and were limited to samples comprised only of women (99-104). Although the magnitude of reduction in FM, FFM and BMD seen in this study is consistent with earlier studies that have used DXA, the present study findings were derived from a sample that included LAGB and LSG with representation from both genders, and are therefore likely to be of greater relevance to most bariatric practices. While the reduction in FM is an expected and desirable outcome of bariatric surgery, the concomitant reduction in FFM is an undesirable consequence of the surgery. This is because decreased muscle mass, which is a component of FFM, has been associated with limitations in mobility and increased risk of falls, particularly among older adults (114, 115). These findings suggest that PA or exercise interventions, particularly resistance training, might be needed in order to preserve FFM during the period of rapid weight loss that occurs over the first few months post-surgery (119). Although there were small reductions in regional measures of BMD, they do not appear to be of great importance, since no changes were found in measures of total body BMD and total body T-scores post-surgery. However, clinicians should be aware of changes in regional measures of BMD, particularly among people who are at risk of, or diagnosed with, osteoporosis (e.g. post-menopausal women).

Pre-surgery, participants presented impaired physical and mental HRQoL, confirmed by a range of validated generic and obesity-related quality of life instruments (566, 574). Findings from the present study support previous reports of significant and clinically important improvements in HRQoL following restrictive bariatric surgery, mainly in physical domains and obesity-related measures, (95, 129, 154, 155, 160, 162, 163, 165-167, 170, 174, 175). At 12 months post-surgery, participants' generic and obesity-related quality of life was comparable to the general population (566, 574). Similar to measures of HRQoL, our findings showed that when compared to pre-surgery measures, there was a significant reduction in weight-related symptoms. This study is the first to demonstrate that the improvement in measures of generic and obesity-related quality of life and weight-related symptoms appears to follow the same pattern of change as measures related to weight, and suggest improved HRQoL does not seem to result in enhanced participation in PA and SB.

Regarding symptoms of mental health disorders, pre-surgery, participants had mild symptoms of depression, anxiety and stress, recorded using two validated measures. The mean scores for the sample pre-surgery for each of these measures were greater than general population normative values (598). The present study also supports previous reports of significant and clinically important improvements in symptoms of depression, anxiety and stress following restrictive bariatric surgery (94, 154, 156, 162, 167, 168, 181, 185, 186, 188). The improvement over the first 12 months post-surgery resulted in participants presenting with similar or lower symptoms of depression and anxiety when compared to the general population at the time of the final assessment (598). Further, our findings showed that the improvement in symptoms of mental health disorders appears to follow the same pattern of change of measures related to weight, and suggest the reduced symptoms of depression, anxiety and stress do not seem to aid with optimising PA and SB.

Clinical messages

This study has demonstrated that, when compared to pre-surgery measures, there was no change in the amount of time participants engaged in PA and SB in the first 12 months following restrictive bariatric surgery. Additionally, estimates of the way in which PA and SB were accumulated were similar at all assessment time points. Of note, 12 months post-surgery, when compared to objective measures collected in the general adult population, the average daily step count was somewhat lower (8,871 versus 9,676 steps/day), and the amount of time spent in SB was greater (73% versus 56% of waking hours) (41, 599). Although caution is needed when comparing estimates of PA and SB as these studies used different activity monitors and applied different criteria to include monitor data in their analyses, these comparisons with data available in the general population suggest that people who undergo restrictive bariatric surgery are at a higher risk of the detrimental health effects associated with little PA and increased time in SB. Addressing PA following bariatric surgery is also likely to be important as participation in low levels of PA has been reported as an important contributing factor to weight regain post-surgery (600-603).

This study highlights the potential importance of the involvement of a multi-disciplinary team in this clinical population to increase PA and reduce SB. Specifically, the data suggest that substantial weight loss, large improvements in self-efficacy to exercise and HRQoL, as well as large reductions in symptoms of mental health disorders and weight-related symptoms were not sufficient to induce a health behaviour change of increased participation in PA and reduced SB. It is likely that in order to change PA, a behavioural intervention which targets motivation, self-efficacy, problem solving, goal setting and commitment to behaviour change is required (75, 604, 605). Such an approach has been shown to produce greater short-term improvements in objective measures of MVPA pre-surgery, when compared to standard care (34). In order to develop such an intervention, further investigation is needed of specific factors related to PA (e.g. perceived barriers, facilitators and motivators to PA) among people who undergo restrictive bariatric surgery.

Regarding goal setting, the present study demonstrated that most of participants' PA was performed at a light intensity rather than moderate to vigorous intensity. Therefore, it is likely that targeting an increase in light intensity PA, as an initial step, may assist with both reducing SB and also serve as a gateway to increased participation in MVPA. Earlier research in overweight Australian adults has shown that there is an almost perfect inverse relationship between light intensity PA and SB (46). Therefore, aiming to increase participation in light intensity PA, rather than MVPA, is most likely to reduce time spent in SB. This is particularly relevant given the recent data which demonstrated the beneficial associations of light intensity PA with cardiometabolic risk factors and the health benefits of interrupting SB with short bouts of light intensity PA (46, 48, 70). For instance, a recent study of adults in the general population has shown that replacing time spent in SB with time in light intensity PA produced significant favourable effects on measures of insulin, insulin resistance and triglycerides (48). Further, targeting to replace SB with light intensity PA in this population could influence the amount of time people engage in MVPA, as demonstrated by previous studies of women and older adults who are obese, with significant reductions in time spent in SB and improvements in time spent in light intensity PA and MVPA following interventions aimed at reducing SB (606, 607). Behavioural interventions are more likely to produce greater effects when they initially target feasible changes in PA (75, 608-610). This is because promoting feasible changes and achievable goals are more likely to increase people's self-efficacy to progress to more challenging activities.

This study is the first to investigate the pattern of change in several outcomes following restrictive bariatric surgery. For those outcomes which improved significantly after surgery, the majority of change occurred in the first 3 months, with less or no change between 6 and 12 months following surgery. This provides information for patients, which is helpful in the formation of realistic expectations for the post-surgical period. Further, this information can inform optimal post-surgical management and timing for interventions aimed at promoting change in PA behaviour. For example, the optimal time to introduce a post-surgery intervention aimed at increasing participation in PA appears to be after the first 3 to 6 months post-surgery, when the majority of weight loss and improvement in outcomes that may be related to engagement in PA, such as self-efficacy to exercise, sleep quality and daytime sleepiness, has occurred.

Strengths and limitations

The main strength of this study pertains to the assessment of objective measures of PA and SB at multiple time points over the first 12 months following restrictive bariatric surgery using two state-of-the-art, highly sensitive monitors that provided robust complementary data. Further, the use of a complex and comprehensive analysis plan, with strict criteria for inclusion of monitor data and the use of exposure variation analysis strengthened the PA and SB findings. Other strengths of the current study include the investigation of changes in outcomes which have not yet been extensively investigated and which are likely to influence changes in measures of PA and SB (e.g. self-efficacy to exercise, cardiovascular fitness, sleep quality and daytime sleepiness). This study is also the first to investigate a large range of important outcomes at multiple time points post-surgery and to demonstrate that, for all outcomes in which restrictive bariatric surgery promoted a significant effect, the changes followed a similar pattern to weight loss. 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 of the present study include the fact that the sample was comprised of people who attended a private practice, which may limit the generalisability of the findings to people who undergo bariatric surgery through the public health system or who have low socio-economic status. Additionally, there was a large number of eligible participants who were not willing to participate in the study, which may also affect the generalisability of the findings, given these people might have different PA and SB levels when compared to those who participated in the study. Since people who presented with any permanent health condition that could compromise the performance of daily PA were excluded from the study, the findings from this study do not extend to this specific group of people. The interpretation of data pertaining to change in measures of obesity-related comorbid conditions was influenced by a low prevalence of such conditions in this sample. However, the findings of this study with regard to weight-related measures are consistent with previous reports (121-130). This confirms the efficacy of restrictive surgery for weight loss was as expected, and thus the effect (or lack thereof) of this surgery on other outcomes occurred in the context of the large degree of weight loss which results from restrictive bariatric procedures. This, combined with similar characteristics in terms of age, gender and BMI when compared to samples from other studies, increases the external validity of the findings of the present study. The fact that the majority of change in those outcomes which improved significantly post-surgery followed a similar pattern of change to measures related to weight supports the association between change in these measures with magnitude of weight loss, as previously reported (93, 104, 113, 138, 160, 167, 381).

Although the comparison of changes in the primary outcome measures with participants grouped according to the type of surgery was not one of the aims of this study, further analysis showed no evidence of differences in the change in measures of PA and SB between those participants who underwent LSG and LAGB. These results should be interpreted with caution due to the small sample size of this study, and future studies with larger samples should aim to investigate differences in the change in objective measures of PA and SB between people who undergo LSG and LAGB. This study, however, had enough statistical power to compare changes in weight-related measures with participants grouped according to type of surgery, which again confirmed that the weight loss following each restrictive procedure occurred similarly to previous reports (121-130). The comparison of changes in secondary outcomes other than weight-related measures (e.g. cardiovascular fitness, self-efficacy to exercise, sleep quality, daytime sleepiness, HRQoL and symptoms of mental health disorders) between groups according to the type of surgery was limited by the small number of participants who underwent LAGB (n = 8), when compared to those who underwent LSG (n = 22).

In conclusion, this study demonstrated no change in objective measures of PA and SB following restrictive bariatric surgery, despite substantial and significant weight loss, as well as significant improvements in several outcomes that could influence PA behaviour. These findings highlight the need for further investigation of specific factors related to PA behaviour among people who undergo restrictive bariatric surgery, as it appears restrictive bariatric surgery itself is not sufficient to effect change in measures of PA and SB.

CHAPTER 5 STUDY 2(A) – RESULTS AND DISCUSSION

Overview

This chapter presents data pertaining to Study 2. The methods relating to this study, including the description of study design, inclusion and exclusion criteria, recruitment process, interview schedule, and data analyses have been described in Chapter 3 (section 3.2 Study 2). Section 5.1 describes the study participants and present data pertaining to the pre-surgery qualitative exploration. Section 5.2 discusses the results presented for the pre-surgery qualitative exploration. The data presented in this chapter has been published in the Obesity Surgery Journal in 2015 (611).

The specific research question answered in this chapter is: prior to restrictive bariatric surgery, what are participants' beliefs about PA, and perceived barriers and facilitators to physical activity (PA)?

5.1 Results

5.1.1 Participants

Between January 2013 to July 2013, a total of 108 people who were obese and scheduled to undergo restrictive bariatric surgery were screened to participate in this study, of whom 70 (65%) were considered eligible. Twenty-three of the 70 eligible people agreed to participate, four of them withdrew before the pre-surgery interview, and 19 (27%) provided written informed consent and were included in the study. A study flowchart is provided in Figure 5.1.

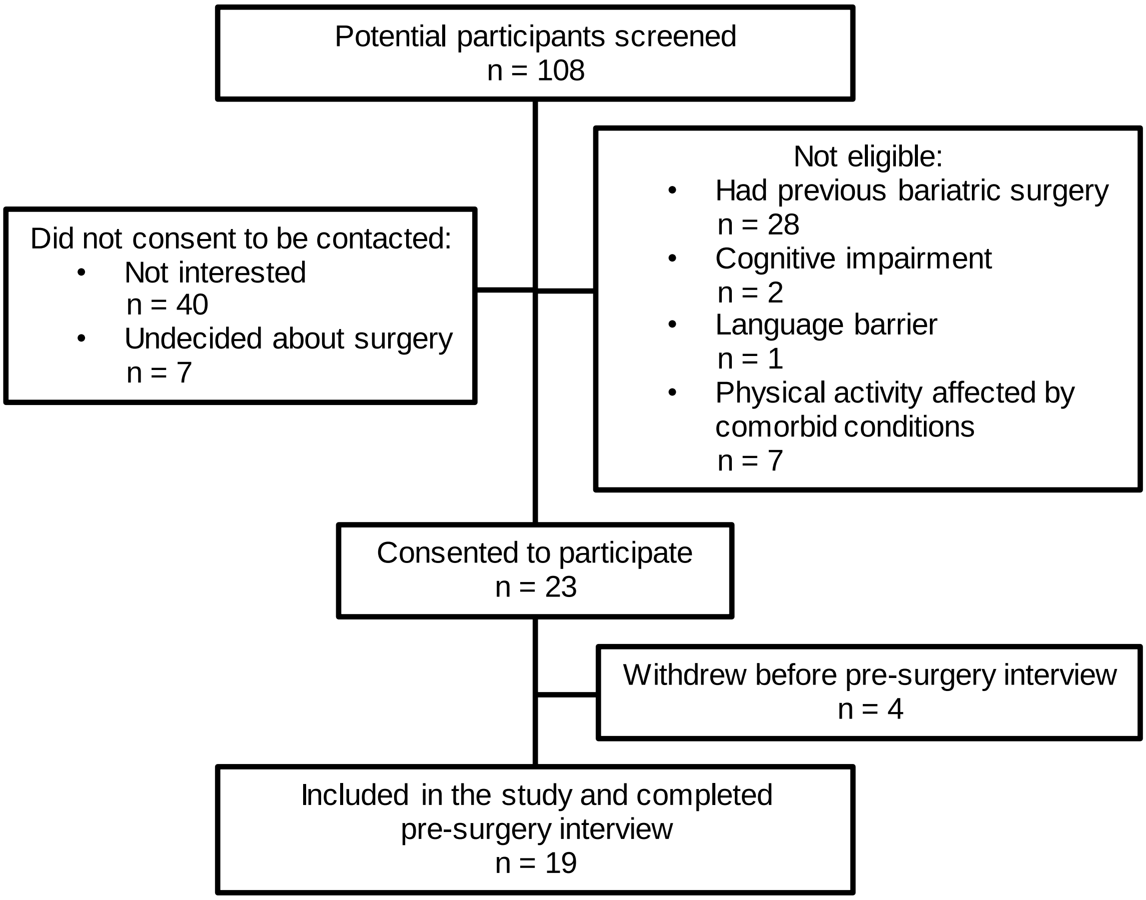

Figure 5.1. Study 2 flowchart.

The characteristics of participants at the pre-surgery interview are presented in Table 5.1. Pre-surgery, the mean age of participants was 41.6 years (range, 19 - 66), weight was 119.2 kg (range, 92.8 - 182.2) and body mass index was 41.6 kg/m^2 (range, 30.0 - 54.2). Participants were interviewed, on average, within one month prior to their surgery. Interviews lasted for an average of 30.6 minutes (standard deviation, 12.5). According to participant preference, five (26%) interviews were conducted in a research room at Curtin University and 14 (74%) at the bariatric surgery practice rooms.

Table 5.1. Characteristics of participants at the pre-surgery interview

Code	Sex	Age (years)	Weight (kg)	BMI (kg/m^2)	Marital Status	Occupation
P1	M	63	115.5	34.5	Married	Manager
P2	M	38	130.0	39.2	Married	Draftsman
P3	F	47	114.0	36.8	Married	Business Manager
P4	F	36	106.0	38.5	Married	Nanny
P5	F	39	92.8	30.3	Married	Office Manager
P6	F	37	100.8	38.4	Married	Function Planner
P7	F	43	93.7	34.8	Married	House worker
P8	F	19	123.8	38.6	Single	Student
P9	F	41	144.0	54.2	Married	House worker
P10	M	66	128.0	42.3	Separated	Entrepreneur
P11	F	32	116.6	42.3	Single	Cost Manager
P12	F	47	125.0	51.4	Single	Research Assistant
P13	F	24	124.4	44.6	Single	Post Office Agent
P14	F	39	106.3	40.5	Single	Nurse
P15	F	50	102.9	37.8	Married	Caterer
P16	F	35	104.4	37.0	Married	Student
P17	F	29	127.6	46.9	Single	Anaesthetic Technician
P18	F	50	125.9	48.6	Married	House worker
P19	M	55	182.2	53.8	Married	Office Manager

Abbreviations: BMI: body mass index; F: female; M: male.

5.1.2 Categories and emergent themes

Data collection and analysis continued until data saturation was achieved, that is, the inclusion of further participants would not alter the main emergent themes (i.e. repetition in key content of themes). Three broader categories were explored in the pre-surgery interviews: beliefs about PA, perceived barriers to PA, and perceived facilitators to PA. The term perceived was used to convey the factors participants believe they experienced or could experience, regardless of whether or not participants truly experienced them.

The emergent themes reflecting the broader categories explored in the pre-surgery interviews are presented in Figure 5.2. The description of the emergent themes and supporting quotes are presented in the following sections. Additional supporting quotes are presented in Appendix 9.

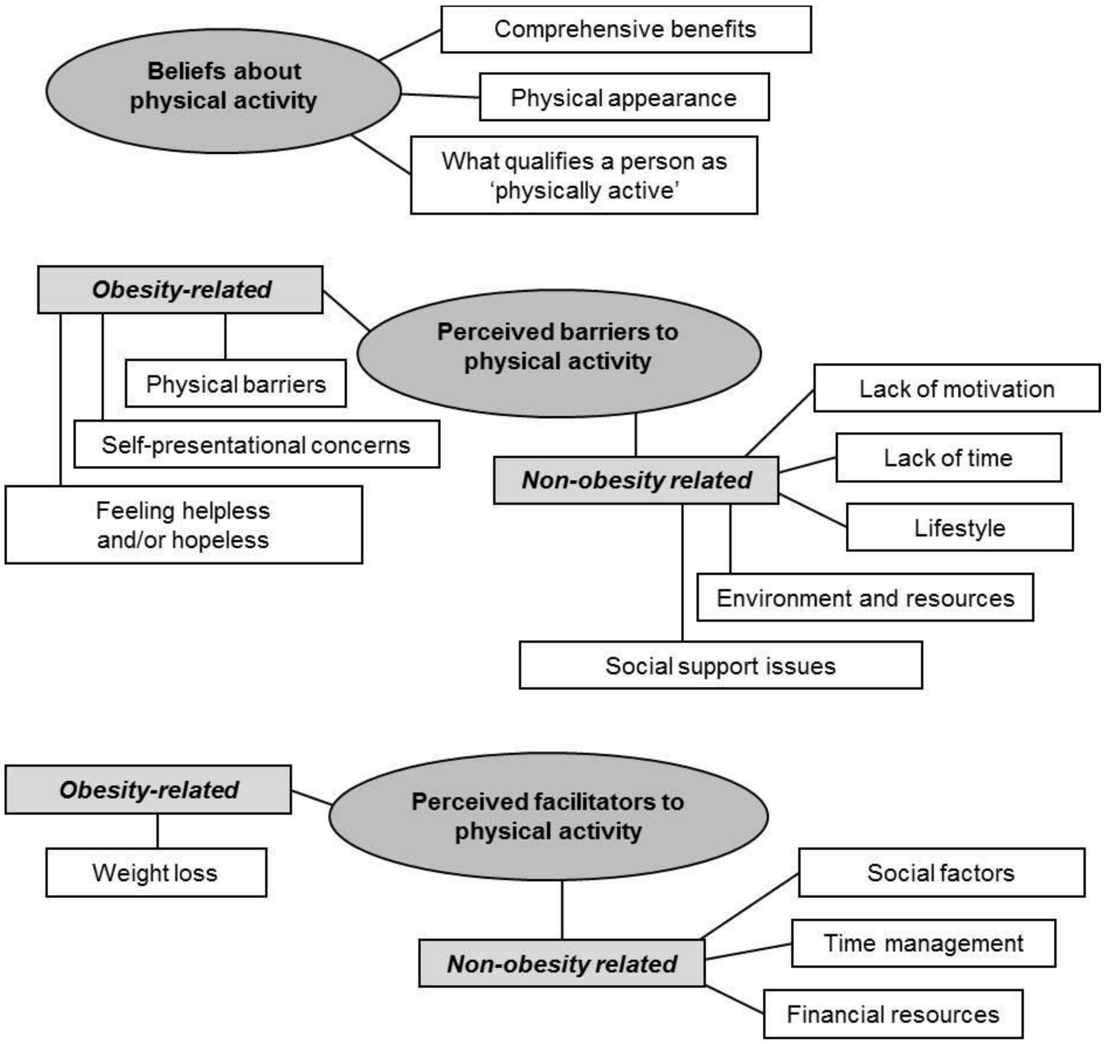

Figure 5.2. Categories and emergent themes from the pre-surgery interview.

5.1.2.1 Beliefs about physical activity

Participants were asked to report their beliefs regarding what it means to be physically active and the health benefits of participation in regular PA.

Comprehensive benefits. All participants reported that they believed participating in regular PA resulted in health benefits, which were largely related to the maintenance of physical health and wellbeing. These beliefs included the influence of PA on mobility, strength and flexibility (P2, P12).

> 'I would say you know, core strength as well as also flexibility…that is something I've noticed I've really gone downhill with, is my flexibility. Umm…yeah, everything from heart, lungs, VO2max through to blood pressure…vitamin deficiencies, just being inside, indoors instead of outdoors.' (P2)

> 'Oh, the fact that it keeps all your joints moving. It keeps you all limbered up. Your joints all going in the right direction.' (P12)

Participants also reported the beneficial influence of PA on fitness and weight management (P5, P8, P17).

> 'You drop your weight.' (P5)

> 'Like losing weight or even just toning up.' (P8)

> 'Healthy heart and just cardiovascular fitness, obviously maintaining a healthy weight.' (P17)

Most participants believed participation in PA was related to increased vitality, as well as better mood and appearance (P4, P11, P16).

> 'Not feeling sluggish or tired or …more energy, absolutely more energy.' (P4)

> 'You feel more energetic, I think you have a slightly better mood as well, sort of, yeah. I mean that's just in terms of mood and all that - but, you know, if you're exercising regularly you don't feel as breathless and things like that when you're doing what should be fairly mundane activities.' (P11)

> 'Oh, things like, you look and feel better and your mood is better and you've got more energy.' (P16)

They also related PA to non-physical benefits, such as improved mental health (P11, P18, P19).

> 'It helps better with your mental health … maybe it helps to lessen those symptoms sort of thing of depression or even that you're gonna get them in the first place.' (P11)

> 'It's good for your mind, definitely is good for your - if you have depression and things like that.' (P18)

> 'Well, I think you get depressed if you are not active, like it's a natural sort of transition to an unhappy state…it's not too many inactive people that are happy.' (P19)

In addition, participants described the role of PA in the prevention of health conditions such as cardiovascular and metabolic diseases (P13, P14).

> 'I guess by pretty much taking care of your heart …bone density…you know I suppose you've got a less chance maybe, unless it's genetic, of getting diabetes and things like that.' (P13)

> 'Increase your metabolism, lower your risk of cardiovascular disease you know, and stroke and blood pressure, you know, reduces blood pressure, umm it could reduce your waist circumference, and also risk of heart disease, diabetes, everything really.' (P14)

<u>Physical appearance.</u> Participants often described a physically active person in terms of positive attributes related to physical appearance, such as complexion (P3, P11, P16), muscularity (P1, P16), fitness (P11, P16) and slimness (P8, P9, P16).

> 'Healthy…toned, glowing I suppose…you know, healthy complexion and everything.' (P3)

> 'They generally look fit, they seem healthy, you know, they've got a nice colour…you know, they don't look pale like me.' (P11)

> 'Someone who is fitter and healthy and they wear clothes that look nice on them and…they enjoy exercise and…they eat well and you know,

> they look healthier and brighter in the face and, and in terms of size I probably would put someone between a 10 and a 12. Size 10 and 12.' (P16)

> 'I guess they are trimmed and suppled and muscly and all sort of things. I guess yeah...it looks as if they enjoy themselves.' (P1)

> 'They'll be like a healthy weight. Yeah, they're slim.' (P8)

> 'Probably not too much fat on them, not overweight.' (P9)

<u>What qualifies a person as 'physically active'.</u> When questioned about what they believe PA meant, most participants believed that a physically active person would be involved in organised sports (P1, P17) or regular exercise undertaken at a moderate to vigorous intensity, such as going to the gym, walking and running (P11, P13, P15).

> 'They play, they participate, play a lot of sports.' (P1)

> 'Someone who exercises regularly… in any form, whether is a team sport or going to the gym.' (P17)

> 'My idea of it is someone who's getting some cardiovascular sort of exercise. I know you've got Pilates and all of that sort of stuff which is good, you know, for your muscles and your posture and all that — but, when I think physically active, I'm thinking someone who, yeah, gets a bit of cardiovascular stuff.' (P11)

> 'Going out and actually exercising, going to the gym. Cardio, walking, bike riding.' (P13)

> 'I would think, you know, any form of, of exercise – sort of walking, running, Pilates. At least four times a week.' (P15)

In contrast, some participants described their perception of being physically active as being able to undertake activities of daily living without barriers (P2, P12, P18).

> 'Not being afraid to sort of get up and do stuff. Being physically active to me is someone who at the moment's notice will get up and do stuff as oppose to think of excuses as to why not to or think of putting it off or

> procrastinating and so forth, so being physically active is someone who is constantly on the go.' (P2)

> 'Well, most people would say, physical activity is getting out there and jumping up and down the street or whatever. For me, it is to be able to get on my knees, to be able to do things like if you're with your girlfriends' kids, or whatever, you can actually be sitting on the ground. You can put your knees down so you can actually get back up…It's also the ability to be able to get out and do the gardening and stuff. I mean, you know, I run around with a lawnmower and that. But by the time I'm finished, trust me, I'm ready for the cardiac ward. But to be able to do just your normal everyday activities without having the hassles that I go through as it is.' (P12)

> 'To be able to do anything you want to do, that is what I think being physically active is, if you decide to climb a hill or mountain, just to do it. If you decide to do a job, just do it.' (P18)

5.1.2.2 Perceived barriers to physical activity

Participants were asked to discuss their perceived barriers to PA. Perceived barriers to PA were defined as factors that prevented or made it difficult to engage in PA according to participants' perceptions. The barriers to PA that emerged from participants reports were both obesity and non-obesity related.

5.1.2.2.1 <u>Obesity-related perceived barriers to physical activity</u>

<u>Physical barriers.</u> Common to the report of all participants was bodily pain as a physical barrier to PA. This pain was mostly described as lower limb and back pain (P9, P15) and was often perceived to be due to the increased load on the joints resulting from the excess weight (P17, P19).

> 'I get a sore back after a while, yeah … I have to stop there and then 'cause it really hurts sometimes, yeah.' (P9)

> 'I mean, at the moment, probably my greatest barrier is sore feet and knees.' (P15)

> 'I get lots of joint pain because of my weight.' (P17)

> ‘My skeletal system has finally succumbed to the excess weight that I'm carrying for a long period of time so…my ankles hurt, my legs swells up, my knees ache, my back, I've got a couple of fractured facet joints in there, so that hurts umm…so it's a lot of pain to do any physical activity.’ (P19)

Extra physical work, in terms of ‘strain’, ‘stress’ and ‘effort’ (P1, P3) or feeling less agile (P2, P9), as a consequence of their excess weight, was also described a barrier to PA.

> ‘Umm...yeah, well I think weight is the big thing, I mean, it's...the more weight more stress on your knees and legs and the less enthused you are and wanting to go out and play a game of golf or have a walk around, that sort of things.’ (P1)

> ‘I think just physically carrying around an extra 40 kilos in weight, you know, it is harder, you know, to even to get out of the car…and stuff like that, it's physically harder…and you know, like I've said, walking down hills and stuff…yeah, it's a big strain, that kind of thing.’ (P3)

> ‘Just my bulkiness, I feel a lot less agile, a lot less…even…everything just takes that much more effort to do.’ (P2)

> ‘I have to have like a three-wheeler one 'cause like on a two-one (bicycle), because my legs are so big, I can't pedal properly and trying to get on to a bike is very hard 'cause I lose my balance. I lose … being this big, you lose all your coordination.’ (P9)

However, being overweight itself was also described as limiting participation in PA, irrespective of whether the excess weight resulted in weight-related pain or bodily strain (P3, P11, P19).

> ‘It's the weight. Yeah, the main thing that's preventing it (doing PA) is the weight.’ (P3)

> ‘I'm hoping exercise will come easier because - and correct me if I'm wrong - I sort of feel that when you're a bigger person, it feels that much harder, or it's a lot more work.’ (P11)

> ‘So there is…being big creates its own limitations.’ (P19)

Self-presentational concerns. Most participants described concerns about their physical appearance in terms of size and engaging in PA in public (P16, P17).

> 'I know I look horrible in the uniform and, you know, I'm scared of people watching me 'cause I look fat.' (P16)
>
> 'There is nothing preventing me physically but because of the way I feel about my physical appearance I don't want to be in a bathing suit and go into the pool…' (P17)

This concern was mostly related to being watched (P4, P12), and the perception of being judged by people due to being overweight (P19).

> 'There have been times when I first joined the gym five years ago, it was very emotional to go, because I… a big girl and everyone else there is skinny and you know…definitely felt like people were looking. So, emotionally, it was hard to go.' (P4)
>
> 'Okay, when it comes to walking around the block or that, I'd rather go walk down the coast where the neighbours can't see me, that's for sure. Umm, same as swimming, I'd rather go swim somewhere where nobody knows me.' (P12)
>
> 'To get on my kayak and don't have people look at you and, you know, look at that fat bastard sort of handling that kayak and…you know, that is…when you are my size that is what people…I'm used to people looking.' (P19)

Feeling helpless and/or hopeless. Feelings of helplessness were frequently described towards weight loss. These feelings were often related to several failed attempts to lose weight through a combination of dieting and increased PA or exercise (P3, P12, P17).

> 'I don't know…because I've been overweight all my life and I've been on yo-yo diets and you know…and you sort of…unless you see…it's quite disheartening when you go on a diet, and they are usually ridiculous, bad strict diets…but you go on a diet and it's ridiculous for a week or so, you know, it's really hard and after a week there is no physical sign that you've lost weight, you know.' (P3)

> 'Yeah, 1996 and it sort of… it goes up and down from there (body weight), backwards and forwards. But really by the time I hit, oh, about 37 years old, I thought I'd stuffed this I'm over it. Accept your body for what your body is.' (P12)

> 'I think it was a combination of things, I don't think I saw the success that I wanted to see (with PA)…I've always really struggled to lose weight even when I've dieted and exercised and I think having worked so hard I've just thought oh, well, what's the point?' (P17)

Further, they reported feeling hopeless about future weight management, also related to using PA as a method of weight control (P16, P19).

> 'I think that also is tied up in the fact that I have got so much weight to lose that it seems such an insurmountable task, almost, so and it's … there's a massive fear of failure in that as well. Like I feel like, why do I bother (to engage in PA) 'cause I'm probably just gonna fail anyway?' (P16)

> 'It sounds like you putting a lot of emphasis on the surgery but I am because without it I haven't got the strength to do it myself so this is a tool to help me have that strength.' (P19)

5.1.2.2.2 Non-obesity related perceived barriers to physical activity

Lack of motivation. Although many participants reported a feeling of wellbeing resulting from participation in PA, there were frequent reports of a lack of motivation (P15, P16), particularly to initiate PA (P4, P5, P9).

> 'No, not physical (barrier) but motivation. I'm not always … I'm not always highly motivated.' (P15)

> 'It's weird, 'cause I feel better when I do it but I still can't get up the motivation to do it every day' (P16)

> 'Yeah, and I like the way I feel afterwards, but sometimes getting there is hard work.' (P4)

> 'Just getting up at the treadmill that's already difficult.' (P5)

> ‘Oh no, yeah, I feel good, I enjoy it. Umm, there's just getting … it's starting it, it's umm … like, 'Oh nah, I don't wanna go for a walk'… Umm, it's just the motivation of getting into it, yeah.’ (P9)

Many participants believed that the lack of motivation was closely related to their perception of ‘being lazy’ (P3, P4, P14).

> ‘I’m just lazy, I’ll put it off pretty much.’ (P3)

> ‘Because I’m too lazy, I can’t be bothered.’ (P4)

> ‘Because I’m lazy, that’s the simple answer.’ (P14)

<u>Lack of time.</u> A common barrier among participants was not having enough time to engage in PA due to the nature of their occupation (e.g. full-time sedentary jobs) (P2, P5, P17) and family responsibilities (P6, P14).

> ‘I mean it’s a very sedentary style…umm…occupation, involves sitting in front a computer screen for 9, 10 hours a day.’ (P2)

> ‘I think it’s difficult being a shift worker because I can’t really commit with a certain day of the week and time of day.’ (P5)

> ‘But obviously during the week you get home really late so there’s no time to actually do that (PA).’ (P17)

> ‘I could … you know, for me, right now, probably my biggest barrier is my time. I don’t have the time to do three times a week or four times a week. So, even, even to walk an extra day just doesn’t seem to happen because I’m running after the kids, you know, with sports and stuff. So, probably my time is my biggest barrier.’ (P6)

> ‘I mean there are some, you know like before, my work is a barrier because umm, if I wanted to take my daughter to the Child Care, it’s only open 9:00 until 12:00. Well I work 7:00 until 3:00 so, so there is no one to look after my daughter while I go to the gym.’ (P14)

<u>Lifestyle.</u> Sedentary activities, such as watching TV or sleeping were frequently reported as leisure time activities (P3, P4).

> 'I just would rather sit on the couch and watch TV than get outside and do something.' (P3)

> 'I quilt, sew and craft, do lots of different crafts, I read and I watch TV and I'd be with my family.' (P4)

When questioned about how they spent their leisure time, most participants indicated a preference for engaging in activities other than planned and structured PA (i.e. exercise) during leisure time (P4, P5, P6).

> 'No, no, why? (laughs) Why would I do that? (PA on leisure time). I just think there are other things I'd rather do than that.' (P4)

> 'So I catch—like on my days off I catch a coffee with a girlfriend or go to the movies with a friend or shopping or what have you.' (P5)

> 'You'd rather be going out with friends more than going to a gym or somewhere.' (P6)

<u>Environment and resources.</u> A small number of participants reported difficulties with coping with hot or cold weather (P1, P5, P9).

> 'I wouldn't have any drama with any except for the weather…if it rains you see…well, I'm not a wet weather type.' (P1)

> 'Through winter where you sort of feel, you know, you can't go outside, it's raining, what have you, can't be bothered.' (P5)

> 'Hot season … I feel sick, yeah. Umm, very … I just get very sweaty and very uncomfortable, very uncomfortable.' (P9)

Some reported a lack of appropriate environment or equipment that would suit a larger person for specific modalities of PA (P2, P16, P19).

> 'The bike riding side of things, I would love to get back on a bike but unfortunately, most bikes aren't really built to take 130kg person pushing it too hard.' (P2)

> 'We don't have opportunities to go and hit a gym or anything down here unless we have to drive 45 minutes away and not many of us do that!' (P16)

> 'I can go back to my kayak, I had to buy a particular type of kayak to carry my weight. Because the one that I wanted umm…would carry a person up to 150Kg and I couldn't buy that so I had to compromise and you know, buy something that could actually probably fit three people on.' (P19)

For some, the lack of financial resources was also identified as a barrier to participating in PA (P12, P14).

> 'I mean, you know, people say, "Why don't you go to the gym?" Hello? Who's got the money to waste going to a gym every day?' (P12)

> 'Hmm, finance; money. You know, I used have a high disposable income. I used to be able to throw money at the trainers you know, and make me thin. (laughs). I don't have that anymore you know. Umm, just yeah some money, gyms are expensive, membership and stuff. I just can't afford that.' (P14)

<u>Social support issues.</u> Some participants considered the lack of company (from family, friends or a professional) to engage in PA or to motivate them as a barrier (P11, P13, P14).

> 'If you're talking about someone who's gonna hold me accountable to exercise and all that, the only person that's gonna do that is me.' (P11)

> 'More probably … no support of doing it (PA).' (P13)

> 'Mm yeah, that's hard because I have to be responsible. You know, there's no one there going, "Woo-hoo, go and do it, go and do it.' (P14)

5.1.2.3 Perceived facilitators to physical activity

Participants were asked to consider perceived facilitators to PA. Perceived facilitators to PA were defined as factors that that helped or made it easier to engage in PA according to participants' perceptions. The facilitators to PA that emerged from participants reports were both obesity and non-obesity related.

5.1.2.3.1 <u>Obesity-related perceived facilitator to physical activity</u>

<u>Weight loss.</u> Losing weight was reported to be the main factor that would make engaging in PA easier (P1, P4).

> 'Oh…just taking the weight off…for me that's all. You know, once this weight starts coming off, it should be a lot easier to do (PA).' (P1)

> 'I think losing weight will make exercise maybe not as challenging as in … I'll have less weight to carry around with my body.' (P4)

This belief was mostly related to the expectation that weight loss would reduce the obesity-related physical barriers described earlier (P17, P19).

> 'Umm…feeling more physically able I guess…some days I feel like an old lady because I find it hard to move being my size so…I think if I felt more mobile and more umm…I think that that would help, yeah.' (P17)

> 'Get my weight off, because with that will come less pain.' (P19)

5.1.2.3.2 Non-obesity related perceived facilitators to physical activity

Social factors. Many participants reported that social interaction or support while engaging in PA would increase their motivation and make the activity more enjoyable (P9, P13, P17).

> 'I feel like if you're with someone when you're walking, you don't feel more, 'Uh, how long is it gonna be?' 'Where are we?' Umm, how many hours I've been out or … you don't think about that when you're with someone. Well just having that person with me to encourage, to carry-get me along. (P9)

> 'Yeah, if I've got company, I'm motivated to do it, yeah. But if it's just me, then it's just boring.' (P13)

> 'It makes it more enjoyable if you exercise with friends and it makes it not just about weight loss, it makes it about doing something social too.' (P17)

In addition, some participants described help from professionals (e.g. personal trainer) and friends as a facilitator to PA (P5, P17).

> 'Yeah, if someone comes, because a couple of years ago I actually had a personal trainer and she came three times a week. And so she motivated me.' (P5)

> 'I think the support that I'll have with the bariatric clinic and with my friends and stuff will make things easier for me.' (P17)

Time management. Some participants expressed that allocating specific time for PA could facilitate participation in PA (P11, P16, P17).

> 'In terms of physical activity, that all comes back down to me, sorting that time issue. I need to be more selfish with my time so umm, I've already had a discussion with my boss around that I can't do everything.' (P11)

> 'Probably not committing myself to so many things in the community and so often.' (P16)

> 'Yes, I think it's getting into a routine and making it a regular thing rather than you know, one day and not for another four days because if you develop a routine and a habit you are more likely to follow through.' (P17)

Financial resources. A small number of participants reported that having more money would facilitate engagement in PA, as this would allow access to a gymnasium (P12, P14).

> 'Right. Give me a million bucks and I'll work it out from there (laughs).' (P12)

> 'Free membership to the gym…Or money to pay the gym trainer umm, yeah umm, yeah. A free year's membership at the gym.' (P14)

5.2 Discussion

The present study is the first to provide an in-depth exploration of beliefs about PA, perceived barriers and facilitators to PA among candidates for restrictive bariatric surgery. Based on 19 interviews of candidates for bariatric surgery, the findings revealed that most participants believed regular PA conferred important health benefits, and that the majority reported they did not engage in sufficient PA to confer these benefits. Most participants also believed that engagement in planned and structured PA (i.e. exercise) or sport is required to be considered physically active. The perceived barriers to PA were both obesity-related (e.g. pain and physical strain, self-presentational concerns) and non-obesity related (e.g. lack of motivation, lack of time). Weight loss was identified as the primary facilitator to PA, and other facilitators not related to obesity were also reported (e.g. social support and better time management).

The most prevalent obesity-related barriers reported by participants were bodily pain, physical strain, and self-presentational issues. These findings are consistent with those from a questionnaire study involving people prior to bariatric surgery in which more than 90% of participants reported physical barriers (e.g. physical limitations, tiredness and pain) and self-presentational barriers to PA (e.g. concern about appearance and clothes) (548). Also, a qualitative study that explored PA experiences of people awaiting to undergo gastric bypass found that excess weight was considered an obstacle to PA, primarily due to joint pain and difficulty due to a bigger body size, in addition to self-consciousness (223). In studies that compared obese adults to their non-obese counterparts, physical barriers such as pain and tiredness, and feeling self-conscious were more frequently reported by people who are obese (217, 224, 543). Napolitano et al (217) investigated self-reported barriers to PA with a questionnaire, as well as their influence on participation in PA in 280 inactive women involved in a 12-week PA promotion trial, and found that reports of feeling too overweight, feeling self-conscious, minor aches and pains, and lack of self-discipline were more frequent in obese participants when compared to those with normal-weight and overweight. Leone et al (224) used an online survey to investigate the reasons why obese women engage in less PA when compared to those in the normal-weight range. Their findings showed that, when compared to non-obese women, those who were obese were less likely to report enjoyment towards exercise (odds ratio, 0.4; 95% confidence interval [CI], 0.2 to 0.8), and more likely to both agree that their weight makes exercise difficult (odds ratio, 10.6; 95% CI, 4.2 to 27.1) and report that they only exercise when trying to lose weight (odds ratio, 3.8; 95% CI, 1.6 to 8.9). Thus, converging evidence from multiple studies, which involved varied designs, suggests that physical issues and self-presentational concerns are particularly important considerations for PA among people who are obese.

The present findings suggest participants have salient barriers regarding feelings of helplessness (i.e. perceptions of lack of control over the environment resulting in negative emotions) and hopelessness (i.e. negative attributions about oneself resulting in disbelief that investments in the future will pay off) towards weight loss and weight maintenance, particularly related to previous weight loss attempts involving diet and exercise. These findings are congruent with a study that explored people's journey to laparoscopic adjustable gastric banding (221). Pfeil et al (221) found that feelings of lack of control over their body weight, and the perception that bariatric surgery is the only viable option after a history of unsuccessful conservative attempts at losing weight were predominant among participants (221). It appears that attributional style (i.e. a tendency to explain events in certain ways) (612) may be an important consideration for PA behaviour of candidates for bariatric surgery. Attributional style is characterised by explanations that are internal or external to the person (locus of causality), and the degree to which the cause is within the person's control (controllability) or permanent versus temporary (stability) (612). The present findings suggest that candidates for bariatric surgery explain their PA experiences as being external, uncontrollable, and permanent primarily as a result of repeated unsuccessful attempts at weight loss with increased PA and diet.

The findings also highlight non-obesity related perceived barriers, such as lack of motivation, self-described 'laziness', and lack of time as key barriers to PA for participants. Perceived lack of time and motivation are reported as the most frequent non-weight related barriers in questionnaire studies of candidates for bariatric surgery (548) and obese women (219, 541), and are among the most commonly reported barriers by non-obese adults in the general population (204, 207). For instance, middle-aged Australian men who participated in focus groups sessions described lack of time to be physically active, due to work and family responsibilities, and lack of motivation to engage in PA as key themes that reflected their perceived barriers to PA (207). The lack of motivation reported by participants can be characterised by a lack of intentionality, which can result from feelings of incompetence, or a belief that the activity will not result in the desired outcome (613). Lack of intentionality, and feelings of incompetence or devaluation of the activity are important aspects of psychological theories of motivation and are related to desistence and avoidance of PA (17, 614, 615). Given studies in the general population have reported similar findings regarding a lack of motivation to engage in PA, it is important to consider that in addition to low motivation, participants in the present study have reported feelings of helplessness and hopelessness about engaging in PA as part of their previous weight loss attempts. Congruent findings among obese populations and candidates for bariatric surgery highlight the potential clinical importance for both the recognition and understanding of the psychological processes (e.g. attributional style and lack of intentionality) that may impact on PA behaviour of people undergoing bariatric surgery, regardless of obesity itself.

This study is the first to investigate perceived facilitators to PA in candidates for restrictive bariatric surgery. Weight loss, the only obesity-related facilitator to PA reported by participants, has been reported as a facilitator to PA in a previous questionnaire study of overweight women (219); however, this study is the first in which weight loss was reported as the main perceived facilitator to PA in candidates for restrictive bariatric surgery. The non-obesity related perceived facilitators to PA described by participants (i.e. better time management, social support, and financial resources) seem to involve factors related to self-regulatory skills, as well as environmental and social contexts, and were similar to those in samples of non-obese adults in the general population (208, 209) and people with chronic health conditions, such as diabetes mellitus type 2 (616) and musculoskeletal disorders (617).

Although post-surgery weight loss may facilitate PA, through reduction of some obesity-related barriers (e.g. extra physical work), it is unlikely to change non-obesity related barriers or influence a person's social support, time availability, or financial status. Obesity-related perceived barriers such as joint pain might still remain, and new self-presentational concerns may result from weight loss (e.g. excess skin). In accordance with this, motivational and physical barriers were the most frequent factors reported by people who underwent bariatric surgery on an online survey assessing post-surgery barriers to exercise (222). A recent qualitative study used semi-structured interviews to explore how participants experienced PA 12 months following bariatric surgery, and found that physical issues, low motivation and self-presentational issues continue to be reported as barriers to PA post-surgery (225).

Clinical messages

Optimising PA in people who undergo bariatric surgery may improve fitness and body composition, reduce surgical complications, enhance recovery, and result in greater weight loss and maintenance (50, 69). The impact of bariatric surgery on participation in PA appears to be, at best, trivial (5, 6) and therefore, this population is still at risk of health conditions related to inactivity (e.g. increased risk of cardiovascular diseases and mortality), irrespective of the weight loss and the improvement achieved in obesity-related comorbid conditions. Achieving change in PA is challenging (192), and some of the perceived barriers to PA identified in this study may be difficult to modify (e.g. financial resources). However, as identification and management of barriers to PA and optimisation of facilitators to PA has been shown to be an integral component of developing behavioural interventions which are effective at producing short-term improvements in objective measures of PA prior to bariatric surgery (34), the findings of the present study provide a framework for clinicians to discuss and address several of the beliefs, barriers and facilitators to PA in people who are obese prior to bariatric surgery. For instance, it would seem important for the staff of bariatric surgery practices to routinely provide educational counselling to this population that PA is not restricted to participation in exercise or sports by informing them of the health benefits associated with reducing sedentary behaviour and increasing participation in light-intensity PA. The educational counselling could involve strategies to decrease sedentary behaviour by interrupting prolonged periods of sitting time with standing and slow walking (43).

In addition to educational counselling regarding the different types of PA, people who undergo bariatric surgery may also benefit from advice on strategies to overcome the non-obesity related perceived barriers to PA that are not likely to change as a result of the surgery alone, such as time management strategies to assist with participation in PA. As candidates for bariatric surgery appear to have low motivation and experience several barriers to PA, it would seem important to promote the use of goal setting strategies that incorporate realistic goals, such as targeting achievable and small changes in PA initially, in combination with regular progression to activities of higher intensity that can be maintained. Additionally, given the frequent reports of feelings of helplessness and hopelessness regarding their lack of previous success in losing weight with increased PA, candidates for bariatric surgery may have low self-efficacy to engage in PA, as well as difficulties to understand the value of PA. Therefore, a focus on educating people who undergo bariatric surgery on the health benefits of PA that have been demonstrated in people who are obese in the absence of weight loss, such as reduction in abdominal obesity and cardiometabolic risk factors (618), could be of benefit to increase their motivation. Earlier research in this population reports that participants believed ongoing support from health professionals, as well as from family and friends, was beneficial to increase participation in PA and this should be considered when designing interventions that aim to optimise participation in PA (225).

Strengths and limitations

The main strength of this study is the in-depth qualitative exploration of beliefs about PA, perceived barriers and facilitators to PA, which provided detailed information regarding important factors related to participation in PA among candidates for bariatric surgery. Nevertheless, the findings of the present study should be considered within the context of its limitations. First, the sample was comprised of people attending a private bariatric clinic, which may limit the transferability of the results to those receiving treatment in the public health system or with a lower socio-economic status. Future studies should consider the investigation of beliefs, perceived barriers and facilitators to PA in these populations, in order to explore the potential differences that might be related to the health services provided and socio-economic status (e.g. limited access to health professionals or higher need for social support). Future research should also consider the way in which factors relevant to PA may change in the context of undergoing bariatric surgery. For example, as bariatric surgery results in substantial and significant weight loss and improvement and/or resolution of obesity-related comorbid conditions, obesity-related barriers and facilitators to PA may change concomitantly. In conclusion, this study provides in-depth information regarding beliefs about PA, in addition to perceived barriers and facilitators to PA in candidates for restrictive bariatric surgery. These data provide a framework for clinicians to develop strategies which target these factors, in an attempt to increase participation in PA in this population.

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CHAPTER 6 STUDY 2(B) – RESULTS AND DISCUSSION

Overview

This chapter presents data pertaining to Study 2. The methods relating to this study, including the description of study design, inclusion and exclusion criteria, recruitment process, interview schedule, and data analyses have been described in Chapter 3 (section 3.2 Study 2). Characteristics of the participants and results of the pre-surgery qualitative exploration have been described in Chapter 5 (Study 2(A) Results and discussion). Section 6.1 describes the study participants and presents data pertaining to the 12-month follow-up post-surgery qualitative exploration. Section 6.2 discusses the results presented for the 12-month follow-up post-surgery qualitative exploration.

The specific research questions answered in this chapter are: Twelve months following restrictive bariatric surgery, (a) what are the perceptions of participants regarding their ability to participate in physical activity (PA) as well as barriers and facilitators to PA? (b) How do these perceptions differ from participants' perceptions pre-surgery? and (c) What are the perceived motivators to PA at 12 months following restrictive bariatric surgery?

6.1 Results

6.1.1 Participants

Follow-up interviews were conducted with 14 (74%) of the 19 participants who participated in the pre-surgery interview. Four participants were lost to follow-up due to non-response to the interviewer's (JZ) contact attempts and one did not undergo the surgery. The themes identified in the pre-surgery interviews of the five participants lost to follow-up did not differ from those who participated in the post-surgery interviews. The characteristics of participants who participated in both pre- and post-surgery interviews are presented in Table 6.1. At the follow-up interview, participants presented with a mean weight of 90.3 kg (range, 60.0 - 152.0 kg), and body mass index (BMI) of 31.7 kg/m^2 (range, 22.3 - 48.2 kg/m^2). The average weight loss was 24% (range, 1 - 40) of pre-surgery weight or 66% (range, 2 - 127) of excess weight (i.e. difference between a person's weight and his/her ideal weight, which is the weight for a BMI of 25 kg/m^2). Participants were interviewed, on average, within 12.7 (standard deviation [SD], 1.1) months post-surgery. Interviews lasted for an average of 32.2 minutes (SD, 11.2). According to participant preference, five (36%) interviews were conducted in a research room at Curtin University and nine (64%) were conducted over the phone. There was no difference between the content of interviews conducted in person or over the phone.

Table 6.1. Characteristics of participants at the post-surgery interview

Code	Type of surgery	Weight (kg)	BMI (kg/m^2)	Weight loss (% of pre-surgery weight)	Weight loss (% of excess weight loss)
P2	LSG	85.0	25.7	35	95
P3	LAGB	94.0	30.3	18	55
P5	LAGB	82.0	26.8	12	67
P6	LSG	68.5	26.1	32	92
P7	LSG	60.0	22.3	36	127
P9	LSG	108.0	40.6	25	46
P11	LAGB	96.0	34.8	18	43
P13	LSG	74.5	26.7	40	91
P14	LSG	69.0	26.3	35	92
P15	LSG	70.5	25.9	31	93
P16	LAGB	100.0	35.4	4	13
P17	LSG	80.0	29.4	37	80
P18	LAGB	125.0	48.2	1	1
P19	LAGB	152.0	44.9	17	31

Abbreviations: BMI: body mass index; LAGB: laparoscopic adjustable gastric banding; LSG: laparoscopic sleeve gastrectomy.

6.1.2 Categories and emergent themes

Six broader categories were explored in the post-surgery interviews: changes in reported participation in PA, changes in perceived ability to participate in PA, changes in perceived barriers to PA, residual perceived barriers to PA, residual perceived facilitators to PA, and perceived motivators to PA. The term perceived was used to convey the factors participants believe they experienced or could experience, regardless of whether or not participants truly experienced them. Residual perceived barriers and facilitators to PA are those reported at both pre- and post-surgery interviews.

The emergent themes reflecting the broader categories explored in the post-surgery interviews are presented in Figure 6.1. The description of the emergent themes and supporting quotes are presented in the following sections. Additional supporting quotes are presented in Appendix 10.

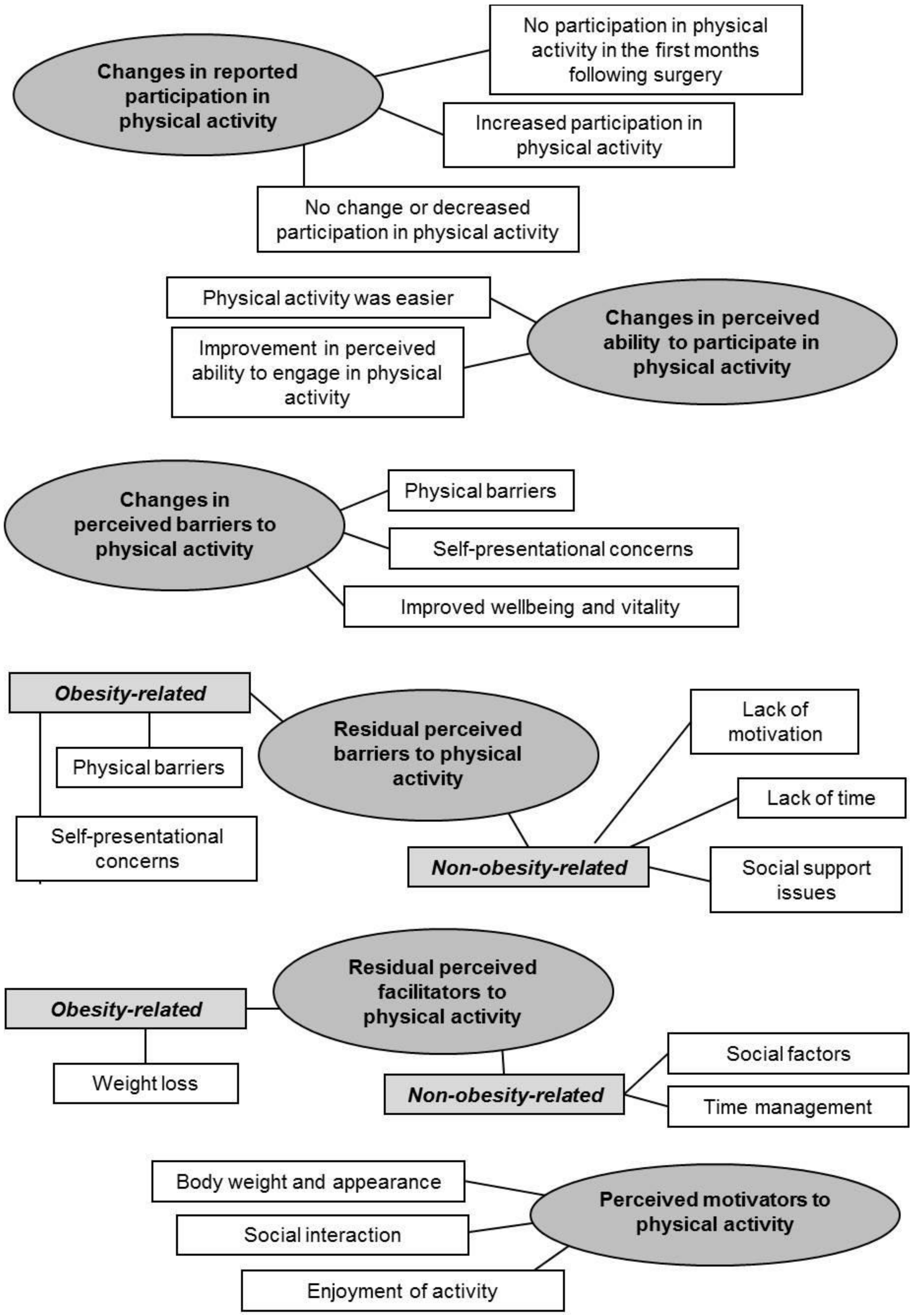

Figure 6.1. Categories and emergent themes from the post-surgery interview.

6.1.2.1 Changes in reported participation in physical activity

Participants were asked to report their participation in PA over the 12 months post-surgery and how this differed from their pre-surgery perceptions.

<u>No participation in physical activity in the first months following surgery.</u> Most participants reported they did not need or want to participate in PA within the first 3 to 6 months following restrictive bariatric surgery (P2, P17), regardless of their pre-surgery participation in PA. Participants explained that as the weight loss was occurring rapidly even in the absence of PA, due to the drastic dietary changes, they believed PA was unnecessary.

> 'So it's only really the last six months that I've made more efforts towards activities. The first six months really was pretty much just not doing much at all.' (P2)

> 'I guess because some days, particularly early on when you're not in the habit of exercising, and you don't necessarily want to because the weight is coming off so easily, you don't really have to exercise. It sounds terrible. Because it always used to feel like a punishment and then all of a sudden you're losing the weight and you don't have to do the physical activity so you know, "Oh well, just you know, I'm doing fine without it." You feel lazy thinking that way, but that's the way it is in the beginning.' (P17)

<u>Increased participation in physical activity.</u> Compared to their pre-surgery perceptions of participation in PA, many participants reported being more active post-surgery. The weight loss of those participants who reported increased participation in PA ranged from 31% to 127% of their excess weight. The reported increase in PA was primarily related to daily life or leisure-time PA (P3, P7), such as playing with their children and walking their dog.

> 'I take the dog for a walk now. I make sure if I come home sometimes from work, and I've had a day where I've been in the office all day, sitting around all day at meetings, I'll come home and go for a walk around the block. Yeah, I just generally am more active.' (P3)

> 'I think that I'm doing more housework. Yeah, doing more housework and not sitting on my ass because I was so heavy. Yeah, we just get out

> more. We do more, go to places. So I'm actually, in this last month or six weeks I've been like walking to the park instead of driving to the park, and walking to the park, walking back, taking my little son. You see, my number one son, we just used to sit around the house, the poor little bugger. And now it's just so different with this little fellow, with number two. We walk into town or we walk, we get on the bikes a bit more. We do a bit more family stuff. You know what I mean?' (P7)

When compared to their pre-surgery perceptions of participation in PA, some participants reported that the increase in participation in PA comprised an increase in both quantity and intensity of planned and structured PA (P6, P17).

> 'I'm still doing my personal training twice a week with the group training. I also jog now. So I jog or walk probably three or four times a week. It just depends how busy I am with work. Between 30 minutes and one hour.' (P6)

> 'I go to yoga regularly now to help with my muscle flexibility and strength. I really enjoy that and I find that it relaxes me as well. It was quite amazing for me doing some of the poses I knew that I would have never been able to achieve in a million years that I can do now because my body has changed, so that's good. Yeah, and I go walking and that, but in the last month or so, I've tried to introduce exercise that gets my heart rate up a bit more. So I'm doing a running training program where you do interval training. You walk for a few minutes, run for a few minutes and build up your fitness until you can just run.' (P17)

<u>No change or decreased participation in physical activity.</u> Compared to their pre-surgery perceptions of participation in PA, several participants reported no change in their participation in PA (P5, P16), or a decrease in the amount of PA they engage with (P14).

> 'Yeah, I've been going walking three times a week. I still just do my walking with friends, and then if they can't come I'll just go on the treadmill. But I haven't joined the gym or anything like that. Yeah, I think it is exactly the same. Well, I haven't pushed myself any further, do you know what I mean? I haven't pushed myself to a higher level.' (P5)

> 'Nothing, really, to be honest. I am not more physically active now. I've played netball for six months (as before the surgery), and I love netball. I love team sports, and that's what I did six months, and I love that. When netball tends to finish, I kind of just fall into a bit of a heap.' (P16)

> 'None. Not really. I've got less activity. I did more before. Carrying her (daughter). That's about it. None, none. No. I walk to the park, but it's like walking from here to the car park. It's not getting my heart rate up, you know? Before, I'd be getting my heart rate up.' (P14)

Some participants indicated that although the quantity of pre-surgery PA was maintained, they believed there was an improvement in the intensity of the PA performed post-surgery (P9, P18), such as engagement in more challenging exercises and an increase in the intensity of walking.

> 'Because we've got a dog, I take her walking probably three times a week, twice a day, for about half an hour. It was a light walk. But now, it's like a brisk walk now, when I walk.' (P9)

> 'Yeah, twice a week it's been (Pilates class, same as before surgery) but the type of exercises are more … the harder exercises. I've just improved in that way.' (P18)

Of note, the lack of change or decreased participation in PA was reported both by participants who lost small amounts of weight (e.g. P16 lost 13% of her excess weight and P18 lost 1%) and those who lost between 46% and 92% of their excess weight.

6.1.2.2 Changes in perceived ability to participate in physical activity

Participants were asked to describe their perceived ability to participate in PA over the 12 months post-surgery and how this differed from their pre-surgery perceptions.

<u>Physical activity was easier.</u> Several participants reported that engaging in PA was easier (P6, P15), and attributed this change to factors related to the weight loss they experienced, such as reduction in obesity-related physical issues that acted as barriers to PA pre-surgery.

> 'Well, I've always done personal training. So I still do that. But it's a lot easier now, and yeah, I can do a lot more and can be pushed a lot

> further. Definitely it's a lot easier. I look back and I think, "Gosh, I could only do that! Now I'm probably doubling or tripling what I used to do". Like before I'd go, "Are you kidding me? I don't want to do that kind of thing", but now I just do whatever has to be done.' (P6)

> 'Physical activity is a lot easier than it was. I'm still not doing enough of it but it's a lot easier than it was.' (P15)

<u>Improvement in perceived ability to engage in physical activity.</u> Participants perceived a greater ability or confidence to engage in PA (P13, P17).

> 'I feel good. Because I'm able to do it as I wasn't able to do it before. Now I can do it, yeah. Physically, I feel like I could do anything and get away with it. Before, I couldn't.' (P13).

> 'Yeah. Well, before, it was sort of the first thing that would pop into my head, was, "Oh no, I can't do that." Now I think, "Oh yeah, I think I could do that. I'd like to try and see. That's something that is within my power to change now (PA levels), whereas before I didn't feel like it was within reach.' (P17)

This perception was confirmed by experiences of performing activities that they did not believe were possible pre-surgery (P9, P14).

> 'We went up North, up Northwest. We walked, and walked, and walked. And I thought, "I couldn't have done this before!" Then, a couple of months later, we went down South. We went whale-watching, and we did a five-kilometre walk. I thought, "I couldn't have done that before, because I wouldn't have had the energy." I would have to my husband, "Nah, I can't, turn around. Let's stop and go back." But I continued. I just walked, and walked, and walked.' (P9)

> 'We've got this big hill where I work. It's massive. It's on a really big gradient. And I used to get sore knees and be puffing when I used to get to the top of the hill to work. And probably embarrassing if anyone was behind me. Now, not even puffing at all. I could run down again, back up again. So that was nice.' (P14)

One participant indicated that the greater ease to engage in PA resulted in a renewed perception of what constitutes exercise (P3).

> 'Where I used to think I was exercising and it was a chore, now that's just normal, active life. I think what I see as exercise now, I didn't before. Before, I used to see everything as exercise - moving almost as exercise, if you know what I mean. The most basic thing was exercise. To me, exercise was hard work and it made you sweat and feel gross, and my face would go red. But now those things don't make me feel like that, so I just do those things normally.' (P3)

6.1.2.3 Changes in perceived barriers to physical activity

Participants were asked to discuss their perceived barriers to PA over the 12 months post-surgery and how they differed from their pre-surgery perceptions. Consistent with the pre-surgery interview, perceived barriers to PA were defined as factors that prevented or made it difficult to engage in PA according to participants' perceptions.

<u>Physical barriers.</u> Most participants who identified bodily pain as a barrier to PA in the pre-surgery interview reported reductions in pain, particularly of the lower limb and back (P7, P15).

> 'Just being able to walk down the beach and in the sand dunes and be able to carry my boy. Far out, it was just … yeah, I can't tell you how bloody unreal it was. My knees, my legs weren't sore, and I was back and forth.' (P7)

> 'I think the main thing is the easing of the physical pain in the feet and knees particularly. I had to have orthotics. Yes, to go for a walk I would have to change into joggers with orthotics. Now, I can walk a couple of kilometres in just whatever shoes I happen to be wearing. When we went to Sydney I didn't have to wear special shoes. Actually, I really noticed it when we went to America, because we did a lot of walking. By the end of the day I'd have had foot pain and knee pain. And it was great. I loved that I could … where you could just walk all day and I was fine.' (P15)

All participants who experienced pain pre-surgery reported a reduction in pain, which was often attributed to the decreased load on the joints that accompanied the weight loss (P6, P13).

> 'I have had nothing. It's just amazing that my feet … I haven't had any injuries or anything. So now all good – I don't have any pain on the heel. Obviously the weight's come off and the feet don't take as much … don't have to hold as much weight I suppose.' (P6)

> 'I don't have pain. I don't suffer from my knee problem anymore, no back problems, as before that would stop me because of the excess weight, and now I just feel good.' (P13)

When compared to their pre-surgery perceptions, participants also reported a significant reduction in the extra physical work they experienced when participating in PA, often referred to as 'strain', 'stress' or feeling unfit (P5, P11, P17).

> 'I huffed and puffed, because it was harder for me to get uphill because I was bringing more … you're obviously carrying more weight. Whereas now I sort of cruise up the hill, so I get up quite quickly. Yeah, I've got more energy, I've got more oomph to go.' (P5)

> 'Physically it doesn't feel like there's so much of a toll either on the legs. I mean, I don't feel like I'm dragging myself around now, yeah.' (P11)

> 'Well, before I used to get short of breath really easily. I climbed to the top, and I actually got to the top before a few of my friends who I thought were slimmer and fitter than me. For me, it was a really special achievement, because I know that I would have never been able to do that, or I would have never even considered it because I would have gone, "No, I can't do that. I'll be in pain." Or you know, "I'm not fit enough."' (P17)

Some participants reported a change in the fear of the physical consequences of obesity they experienced pre-surgery (P3, P13)

> 'I don't feel like I'm going to have a heart attack, and I can get in and out of cars without straining.' (P3)

> 'I don't think I've ever like done so much effort in 45 minutes (in a personal training session) to be honest. Like luckily, I'm a smaller person now because I don't think my heart would have taken it if I was bigger. I would probably die of a heart attack if I was to do it.' (P13)

Self-presentational concerns. Pre-surgery, participants reported feeling self-conscious and worried about people's judgement when engaging in PA in public. Following surgery, most participants reported not being as concerned about people's thoughts, nor feeling 'judged' because of their size as they did pre-surgery (P3, P17, P19).

> 'That's very different (feeling self-conscious when engaging in PA). I don't feel so out of it now. I feel more normal. And yeah, I do feel like, in my own mind feeling better. Even though nobody has actually changed towards me, it's the way I feel, it has made a difference in my perception of what people think of me.' (P3)

> 'Well, before when I went out walking or whatever, even though it wasn't necessarily a rational thought, I always felt like everyone was staring at me. Particularly if I was in a place like a gym, I felt like a fish out of water, because I was this morbidly obese person in the gym with people who looked fit and healthy and slim. Now, I don't feel like I stick out like a sore thumb. I can go out and do my running or I can go to yoga. I can go to those places though and just feel normal. I just feel like I blend in, which is great.' (P17)

> 'I don't walk into a room feeling that people are looking at me, thinking, "Oh, Jesus Christ, he's huge," and things like that. I'm a bit more comfortable with myself so I'm able to socialise more and be very comfortable, more active.' (P19)

Improvement in wellbeing and vitality. Compared to their pre-surgery perceptions, several participants reported improvements in their perceived wellbeing and vitality (P5, P9). Participants explained that the pre-surgery perceptions of low energy and health impairment influenced their participation in PA.

> 'So yeah, I feel healthier. I've got more energy. I have lots more energy, some days I wouldn't want to get out of bed, you feel really lethargic because of that extra weight holding you down. Whereas now, I'm up early, and out and about doing things, and I feel good, I feel really good. I don't know, just a lot more energy.' (P5)

> 'I just had no energy at all. I just felt lifeless. Just my outlook on life, I just see my life differently now … a lot happier. I'm a lot happier. My diabetes.

> That's under control now. My cholesterol, my blood pressure – that's all under control...' (P9)

6.1.2.4 Residual perceived barriers to physical activity

Despite the aforementioned reports of improvements in obesity-related barriers to PA, several participants reported that some of the obesity-related physical and psychological barriers to PA reported in the pre-surgery interview remained at 12 months post-surgery. Many of the non-obesity related barriers to PA identified in the pre-surgery interview remained post-surgery.

6.1.2.4.1 Residual obesity-related perceived barriers to physical activity

Physical barriers. Despite the theme of positive changes in pain as a result of the surgery, some participants reported that pain was not completely resolved, and that it consequently remained a barrier to PA. The persistence of pain as a physical barrier to PA was mostly reported for those participants who experienced chronic issues such as chronic low back pain (P5) and osteoarthritis (P19).

> 'And I've always suffered … the reason why I had the operation was because I suffered from a lot of back pain, and I still do but not as much.' (P5)

> 'Pain, still the fear of ... both my ankles, I've had ligament surgery and bits and pieces and the bone fragments so very, very unstable. So walking for me is a concentrated effort rather than ... I can't walk on uneven surfaces with any confidence. My left knee is just starting to flare up again at the moment.' (P19)

The fear of pain also appeared to act as a barrier to PA for P19, who despite a substantial loss of 31% of his excess weight was still obese at 12 months post-surgery.

> 'Look, the main things are obviously getting out in the cold air has certainly been a major barrier and the other is, yeah, just I suppose the pain, the fear of or the lack of confidence, I suppose, in my limbs, my lower limbs.' (P19)

Self-presentational concerns. When compared to their pre-surgery perceptions, some participants reported residual self-consciousness regarding their physical appearance or size when engaging in PA, particularly for exercise in a group setting (P11, P19).

> ‘Yeah, I think if I was exercising in a group environment like doing boot camp or things like that, I’d still be self-conscious about it, yeah.’ (P11)

> ‘If I was feeling accepted, I would ... if I went into a gym, I would feel like the odd one out, I suppose, so I avoid those circumstances. So getting out and doing exercise in a public beach with my kayak still isolates me from the rest of the world but going to a gym means you're in a confined space with people who are generally, they're pretty hot. They're pretty muscley. You are really, really the odd one out. No matter what you're there for, you are.’ (P19)

For other participants, there was a shift in focus regarding their self-presentational concerns, which was related to excess skin resulting from weight loss, rather than the pre-surgery concern about the excess weight (P15, P17).

> ‘Oh, certainly with swimming … I mean, I've got a bit of loose skin. You're sort of aware of that. But then I'm 51. But a bit more loose skin than you would have’ (P15)

> ‘I think while I do feel a lot better about how I look and how I feel about myself, I think it's going take time for me to feel really happy with my body, because now I've got loose skin. In some ways, I feel like I still have self-image issues, but they're just slightly different. Rather than it being about my thighs, it's about how my body has changed, and I have loose skin and stuff.’ (P17)

6.1.2.4.2 <u>Residual non-obesity-related perceived barriers to physical activity</u>

<u>Lack of motivation.</u> Several participants reported that lack of motivation remained a barrier to PA (P5), which for some was linked to a perceived lack of discipline or laziness (P14, P15).

> ‘I just need to push myself. I mean, that’s the thing – I’ve got get my head set around like, if I do want to join a gym and go, and do that sort of thing again like I used to years ago.’ (P5)

> 'Just put lazy. I guess now I'm at maintenance, nearly at maintenance, so I need to be looking at toning up. I know when I need to tone up, so I've got some free weights at home. But I could've been doing that already and have nice arms, but I haven't, because I'm lazy. I'm like, "Oh, I'll do that next week, next month".' (P14)

> 'Lack of motivation it would appear. And lack of organization. But I will have to think about what motivates me, because clearly I'm not a highly motivated person. Apparently self-discipline has to come in, or organisation has to come in. I think it's not a nice realization to come to, but I think I'm a naturally … in some ways I'm a naturally lazy person' (P15)

Specifically, many participants reported lack of motivation to engage in PA in the first few months post-surgery. Participants explained that they were not motivated to engage in PA during this period since considerable weight loss was happening as a result of the drastic dietary changes (P2, P14, P17). The lack of motivation to engage in PA in the first few months post-surgery was mostly reported by those participants who lost over 80% of their excess weight in the first 12 months post-surgery.

> 'One of the interesting things that I found about having gone through the operation is in that first probably two- to three-month period, because you're on very restricted calorie and volume amounts, I was losing quite a lot of weight without really doing anything. So there is a certain level of apathy that sets in, where you just think, "Well, it doesn't matter what I do. So long as I just stick to that amount of volume of food and that type of food, I'm going to keep losing weight anyway." So, I guess the drive to back that up with doing something physical, activity-wise, wasn't really there. Because I was getting good loss of weight without doing anything.' (P2)

> 'Don't need to exercise because I'm losing weight. Now I'm losing weight, so the motivation to do that is gone. I have all of them (benefits of PA) without doing the exercise [laughs]. Do you know what I mean? And I've always been lazy, but I did that before (PA), because I knew I had to at least make an effort and try and lose weight. But now I don't need to make an effort because it's just happening by itself.' (P14)

> ‘Definitely in the beginning when your weight loss is coming off so rapidly, you think, “Oh, well, I don't really need to. [laughs]. I'd go for a walk every now and then, but it was just … in some ways, it's scary how fast it comes off (the weight), and you sort of like you go, “Oh gosh, I don't want it to come off too fast”.’ (P17)

Lack of time. Several participants reported that a lack of time to engage in PA due to work and family responsibilities remained a barrier to PA (P2, P5).

> ‘It's all that I can do at the moment, with the kids and with work. I don’t have time for anything. I like doing it. It's not something I get to do a lot of, because I've got a pretty sedentary sort of job and so forth, and the kids keep the rest of the time active. But when I do get to go for a ride or catch up with friends and go do other stuff, it's good. I enjoy it. And I feel pretty good doing it.’ (P2)

> ‘But then I look at my … the main days that I do my exercise are the days that I have off, but when I work, we leave home at seven o’clock in the morning, we come home at 6.30 at night, so it’s really difficult. You come home and you’re tired, it’s been a long day, and then you got to cook. So that’s why those sort of days you don’t really do any exercise. So it’s mainly the weekends and the couple of days that I have off during the week. If I was home all day, you’d have plenty of time to do exercise. [laughs]’ (P5)

Although participants did not report it as a perceived barrier, the following quotes suggest that participants did not believe PA was of sufficient importance to be prioritised against other aspects of daily life (P3, P7, P11).

> ‘I’ve just started doing Pilates videos, so I’m going to try and do that three times a week. Yeah, that’s sort of just now, start training a bit more, training my body up a little bit more. Other than that it’s mostly just walking, playing with my daughter and sometimes bike riding.’ (P3)

> ‘No, just been touching on a bit of Pilates to strengthen up my pelvic floor area and my lower back. And that's probably what I'll continue to do and I'll do more sessions of that. I've been doing one a fortnight which is way better than anything yet and then I'll slowly move into that. We've got a busy couple of months coming up and then I'll lock in.’ (P7)

> 'I did enrol for boot camp, and then they cancelled it, but I did see another sign for boot camp across the road from my work, so I did say that I was going to do that when I get back to Melbourne next week, go and enquire. Fingers crossed. [laughs]' (P11)

<u>Social support issues.</u> Some participants reported that the lack of company to engage in PA and lack of support with family responsibilities such as child care remained a barrier to PA (P5, P14, P16).

> 'I mean I'd always like to do more. If I had … see, that's the thing – not that I need motivation, but I like to go walking with somebody. I don't like to go by myself. So when I've got a walking partner, I'd go every day. But unfortunately, I haven't gotten a walking partner three days, so that's why I'm limited to that 3-4 times a week.' (P5)

> 'She (daughter) won't go in the pram anymore, and she won't walk very far. So that's my walk out. If I want to go for a walk, I have to go by myself, and that's very difficult to do, because she's always with me. So that's a barrier.' (P14)

> 'I try to get out and go for a walk or a run or something, and just because it's me, on my own, doing it myself, I'm not accountable to anyone, I just don't do it, because I've got assignments to do and everything like that. It's all busy, so I think, "I'll just do this, and I'll exercise later," and it never happens.' (P16)

6.1.2.5 Residual perceived facilitators to physical activity

Participants were asked to discuss their perceived facilitators to PA over the 12 months post-surgery and how they differed from their pre-surgery perceptions. Consistent with the pre-surgery interview, perceived facilitators to PA were defined as factors that participants perceived to help or make it easier to engage in PA.

6.1.2.5.1 <u>Residual obesity-related perceived facilitator to physical activity</u>

<u>Weight loss.</u> Weight loss remained the main perceived facilitator to PA. Participants who reported an increase in PA post-surgery explained that the effect of weight loss on their physical barriers and perceived ability to engage in PA was the main facilitator for the change in PA (P2, P9, P13).

> ‘Because I was lighter. There was less stress on my knees and ankles and so forth. So walking and even simple things like going upstairs and so forth, you were no longer out of breath doing so.’ (P2)

> ‘Just knowing that I’ve lost all this weight, and just knowing that I can do it. I can do the walking, and I know I can do the exercises now.’ (P9)

> ‘Being lighter. I was able to get out there and do it, yeah.’ (P13)

6.1.2.5.2 Residual non-obesity related perceived facilitators to physical activity

Social factors. Some participants reported that having company to engage in PA remained a facilitator to PA. The increase in perceived ability to participate in PA reported by participants appeared to enable them to engage in PA with friends or family members (P17).

> ‘I have lots of friends and family members who like things like say, cycling or running, and before I never felt like I could join them in those activities. So now I feel like I can, so I definitely think it's a maintainable thing.’ (P17)

One participant, who reported an increase in participation in specific types of PA that he found enjoyable following surgery (e.g. kayaking), indicated that having company would facilitate engagement in activities he would not normally do.

> ‘My son is fairly active now and we’ll catch up with him. He's moved back closer to Perth so I sort of see him once a month and we'll go walking and things like that.’ (P19)

Another participant, who reported a decrease in participation in PA post-surgery mostly due to lack of motivation and family commitments, reported that participation in PA would be easier if she would have someone to help with child care and to engage in PA with her.

> ‘Somebody looking after (child’s name), and then another friend saying, “Come on, let’s go out for a walk together”.’ (P14)

Time management. For some participants, better time management in order to prioritise time for PA was found to facilitate their participation in PA (P11, P17).

> ‘Then you come to the exercise that I’m actually in a bit of a routine now because I’ve got the work hours under control.’ (P11)

> ‘Sometimes, I might have a week where I just don't have the time to do as much (PA) as I normally do, but then the next week when I've got more time I get back into it. Do you know what I mean?’ (P17)

6.1.2.6 Perceived motivators to physical activity

Given lack of motivation was a frequently reported barrier to PA in the pre-surgery interview, at the post-surgery interview, participants were asked to report on their motivators to PA. Perceived motivators to PA were defined as factors that participants perceived to make them want to engage in PA.

Body weight and appearance. The main perceived motivators to participate in PA for most participants were additional weight loss and/or maintenance of the weight loss achieved post-surgery, as well as to improve their physical appearance. These motivators were described by both those participants who reported no change or decreased participation in PA (P5, P14, P16) and those who reported increased participation in PA (P13, P17).

> ‘To lose more weight. Or to look good, and to fit into clothes, [laughs] some old clothes that … nice clothes that I haven’t fit into for many years. Oh – to maintain, because basically, I’ve known all my life, if I don’t do exercise, I gain weight. So regardless of what I eat, it’s … obviously, I’ve got a sluggish metabolism that I need to do exercise, some form of exercise. I guess sometimes when you still look in the mirror you see … I mean you know you’ve done well and you’ve lost weight, but I try and still push myself to lose some more, because I really think that I should be able to move those extra five kilos if I work harder.’ (P5)

> ‘I know I need to tone up my arms, so I need to start doing my weights. I haven’t started that yet. I’m in the pre-contemplation phase. Yeah, yeah. So summer’s coming, so I know that a lot of the dresses that I’ve got are sleeveless, so yeah. That will be a motivation to … yeah, tone up my arms. You don't tone up your arms by walking.’ (P14)

> ‘I want to say to lose weight. Sometimes when I get a really, really strong willpower, I know there’s nothing that will deviate me from doing exercise

> every day, and I feel guilty if I miss a day. Yeah, so I guess the number one motivator for me is to lose weight, and that comes back to associating it with loss of weight.' (P16)

> 'Well, I knew there would have to be a time that I would have excessive skin, so I just thought I'd get onto that before me having that problem of having another surgery just to get rid of the excess skin but yeah, me getting onto that has made it a bit better.' (P13)

> 'Like I said before the last … it will feel so ... like I was told I would only get down to 90 kilos, and it felt amazing when I went further than that. I just think it will feel amazing if I get to say 68 kilos, which is what I'm meant to be and to be a normal BMI. I think that will be an amazing feeling and a feeling of achievement and accomplishment, and I never ever imagined that I would ever be able to get to 68 kilos. Whereas now I can imagine it and I can see that it's possible, so that has a huge part in motivating me to exercise. Over the last few months, I have made an effort to be more active. Not that I didn't do any exercise before, but now, because I would like to lose those last 15 kilos, I'm thinking more about what I can do physically, in terms of physical exercise to help that.' (P17)

Additionally, some participants reported that wanting to improve their fitness levels also motivated them to increase their participation in PA (P9, P17).

> 'Just wanting to get fit, just wanting to lose a bit more weight and just be a bit more healthy.' (P9)

> 'I think definitely when my weight loss slowed down, right down -- I lose about a kilo a month now -- that's when I started thinking more about aerobic exercise that it would increase my fitness.' (P17)

<u>Social interaction.</u> Some participants reported that they were motivated by the social aspect of engaging in PA with someone else or with a pet (P9, P11, P13).

> 'My husband sometimes comes with me when I go walking. That's good, because you can talk. He motivates me to keep going, and I motivate him to keep going, so we both motivate each other.' (P9)

> 'A little bit of guilt that the dogs have been home all day. They live in a small yard now, so they need that stimulation to go out. That's a

> motivator to be a responsible pet owner, [laughs] to get them the exercise. I know it makes them happy, so it makes me happy. That's my main motivator, my little babies.' (P11)

> 'Just for that motivation to keep going, that nothing in life can stop me now. And just to maybe like even go out there and meet new people with my PT or whatever. I think because we live like right near Asheville Reserve, so there is like always something happening there, and especially the motivation to have a look at hot Italian guys playing soccer. That's a great motivator. Good motivator.' (P13)

Enjoyment of activity. A small number of participants reported that choosing to engage in types of PA they find enjoyable was a motivator to participating in PA (P2, P6).

> 'It's something I did when I was a kid, and the enjoyment of it has not diminished, which is great. You enjoy it for what it is rather than feeling … so like I can do things and enjoy the activity, rather than thinking about how I'm feeling in the activity. So you're enjoying the scenery or the company or the conversation. Whereas in the past, it was more about how do you feel in that situation.' (P2)

> 'Hmm, what motivates me? I do love it. I just love doing it. So it's not something I think, "Oh gosh, I've got personal training tonight." You know what I mean? I just love going, and it is a social aspect as well, but I do like …I think now, I just realized that the diet … you have to have a good diet and you have to push yourself to maintain what you've lost, basically. And I think that's in the back of my head as well. You've got to keep doing this. You know? But I think I just love it more than anything. I think always my head's loved the sport and loved that kind of thing, but the weight definitely put me off unfortunately. No, I love it. I love it. I still always liked it, but I absolutely love going and I definitely push myself now to my limits, especially on those personal training sessions.' (P6)

6.2 Discussion

This study is the first to provide a longitudinal, in-depth exploration of people's perceived ability to engage in PA, and perceived barriers and facilitators to PA following restrictive bariatric surgery, including how these factors changed over the first 12 months following restrictive bariatric surgery. Additionally, this study is also the first to explore factors people perceived to be motivators to PA over the first 12 months following restrictive bariatric surgery. Findings from 14 participants who were interviewed pre-surgery and 12 months post-surgery revealed that most participants reported not engaging in PA during the first 3 to 6 months post-surgery. Participants reported an increase in perceived ability to engage in PA, mostly described as a result of the reduction in obesity-related perceived physical barriers to PA achieved with weight loss. Regarding perceived barriers to PA, although there were reports of improvements in some obesity-related barriers to PA (e.g. bodily pain and self-presentational concerns), many participants indicated that there were residual obesity-related perceived barriers to PA and for some there was a shift in focus regarding self-presentational concerns (i.e. from excess weight to excess skin) from pre-surgery to 12 months post-surgery. Most participants reported that pre-surgery non-obesity related perceived barriers to PA (e.g. lack of motivation and lack of time) were still present at 12 months post-surgery. Perceived facilitators to PA were consistent between pre- and post-surgery interviews being weight loss, social factors and time management. Regarding motivators to PA, at 12 months post-surgery, weight loss and improvement in physical appearance were most commonly reported, and some participants also reported social interaction and enjoyment of PA.

Although some participants reported an increase in their participation in PA after the first few months post-surgery, many reported no change or decreased participation. Regardless of whether their reported participation in PA had changed, most participants indicated that they did not engage in PA during the first 3 to 6 months post-surgery. Participants often explained that they did not find the need or will to participate in PA during the first few months post-surgery due to the substantial weight loss achieved as a result of the drastic dietary changes. These findings suggest that the optimal time to promote changes in PA may be approximately 6 months post-surgery, when a substantial amount of weight had been lost, weight loss had started to slow down, and people appeared to be more receptive to engaging in PA.

The participants who reported an increase in participation in PA indicated that the increase was primarily related to daily life and leisure-time PA, rather than planned and structured PA (i.e. exercise). The increased participation in daily life and leisure-time PA, rather than planned and structured PA, might be explained by the fact that participants reported feeling more able to engage in everyday tasks that had previously been difficult or impossible (e.g. walk to the shops or run around with their children). As most participants did not engage in planned and structured PA pre-surgery, this study reveals that surgery did not change the way in which people participate in PA (i.e. daily life and leisure time PA versus exercise). This finding supports earlier research demonstrating that participation in PA is determined by multiple factors (74), and is consistent with a recent qualitative exploration that interviewed two women at four different times over the first year following gastric bypass (619). These women reported they believed to be more active following surgery, due to increased daily life PA, but did not increase their participation in planned and structured PA that had been recommended by health professionals.

Participants reported that PA was easier post-surgery, and attributed this greater ease to the substantial weight loss achieved and consequent reduction in the pre-surgery obesity-related perceived barriers to PA, such as bodily pain. When compared to pre-surgery perceptions, participants reported an increase in their ability or confidence to engage in PA that was reflected by participant reports of performing activities they did not believe were possible pre-surgery. Previous cross-sectional qualitative studies have reported that participants believed themselves to be more able to engage in PA between 6 to 12 months following gastric bypass, and attributed this increased ability to a reduction in obesity-related physical barriers to PA (225, 619, 620). Self-efficacy, defined as the belief that one has the ability to successfully engage in a specific behaviour, has been recognised as a main determinant of change in PA (74, 75). According to Bandura's theory of self-efficacy, different factors may influence people's perceived self-efficacy to PA, including their interpretation of physical and emotional reactions when engaging in PA (e.g. anxiety due to increased heart rate when engaging in PA), personal mastery of PA tasks (e.g. accomplishments related to PA), verbal persuasion (e.g. encouragement and/or feedback delivered by important others), and modelling experiences (e.g. observing someone similar to oneself succeeding in PA-related tasks) (73). At 12 months post-surgery, participants reported positive physical and emotional reactions to PA as a result of a greater ease to engage in PA, as well as the experience of mastering activities they previously believed they were not able to perform, which likely enhanced their perceived self-efficacy to engage in PA.

The present findings show that although participants reported improvements in some of the obesity-related perceived barriers to PA (e.g. bodily pain and self-presentational concerns) when compared to their pre-surgery perception, many reported that these barriers were still present post-surgery. These findings are consistent with previous research on barriers to PA and experiences of PA following bariatric surgery (222, 225, 620, 621). For instance, a recent study using an online survey in 366 people who underwent bariatric surgery showed that bodily pain and presence of chronic obesity-related comorbid conditions were frequent physical barriers (222). The present findings highlight not only that pain might still act as a barrier to PA post-surgery, but that for those people who experience chronic obesity-related comorbid conditions (e.g. osteoarthritis) or who are still overweight, fear of pain and/or injury might also act as a barrier to PA. In a study that investigated changes in self-reported PA and exercise cognitions following restrictive bariatric surgery, fear of injury was also found to be a barrier to PA at 1 year, and a predictor of reduced participation in PA at 2 years post-surgery (621).

Regarding self-presentational concerns, the presence of excess skin resulting from substantial weight loss was described as a new barrier to PA. Similarly, a cross-sectional qualitative study that explored people's experiences, on average 28 months following gastric bypass, found that excess skin was commonly reported as an undesired consequence of weight loss (620). Their findings showed that some participants reported to be more self-conscious about the excess skin than they had been about being obese.

The present findings also highlighted that several non-obesity related perceived barriers to PA identified pre-surgery, including lack of motivation, lack of time, and social support issues persisted at 12 months post-surgery. Specifically, participants reported low motivation to engage in PA during the first months post-surgery due to substantial weight loss. Findings from the pre-surgery exploration of participants' perceived barriers to PA showed the presence of feelings of helplessness and hopelessness towards weight loss and weight maintenance (611). As a result of unsuccessful attempts at weight loss using diet and increased PA, participants appeared to believe that their PA behaviour was permanently outside of their control. Although participants believed that regular participation in PA results in extensive health benefits, their previous experiences of participation in PA were primarily concerned with weight loss. Given participants generally experienced weight loss post-surgery without increasing their participation in PA, they perceived

PA to be unnecessary post-surgery. A lack of intentionality (i.e. people may not want to engage in PA) and devaluation of the activity (i.e. people may not value the outcomes of PA enough to engage in regular PA), as well as a lack of willingness to invest the necessary effort to overcome the residual perceived barriers to PA (e.g. learn and apply time management strategies to overcome lack of time as a barrier to PA) seem to contribute to the lack of motivation to engage in PA that was reported by participants in the post-surgery interview. These factors are consistent with the concept of amotivation (i.e. lack of intention to act) and are associated with avoidance and desistance of participation in PA (16, 17, 613, 622).

Perceived lack of time has also been frequently reported as a perceived barrier to PA in previous studies involving people who underwent bariatric surgery, people who are obese, and the general adult population (207, 219, 222, 548). Although participants did not report it as a barrier, the present findings suggested they did not believe PA to be important enough to be a priority. Most people have multiple concomitant goals in everyday life (e.g. succeed at work, spend time with family and friends, maintain a healthy lifestyle) that may conflict when they compete for the same resources (e.g. time, money) (623, 624). Goal commitment (i.e. the determination to reach a goal) is usually based on the belief that a goal is both desirable, which is determined by the expected value or attractiveness of the activity, and feasible, which is determined by one's belief they can achieve the expected outcome by their own effort (625). Participants appeared to experience conflicting goals regarding participation in PA and other activities, such as family and/or work responsibilities, which was likely influenced by the devaluation of PA, resulting in lack of prioritisation of PA (626). Similarly, the results of an online survey highlighted that lack of motivation was a commonly reported barrier to exercise among people who underwent bariatric surgery, which was related to difficulties with participating in regular PA and making PA a priority (222). Social support issues, such as lack of support with family responsibilities and lack of company to engage in PA, have also been previously reported as a barrier to PA by people following bariatric surgery (222, 225). Social support issues are also likely to influence people's belief regarding the feasibility of regular participation in PA, and therefore negatively influence their commitment to participate in PA. A recent qualitative study found that the need of support from family, friends and health professionals in order to be physically active was a salient theme at 12 months following gastric bypass (225). Although previous investigations were cross-sectional in nature, converging evidence from different studies suggests that the substantial weight loss achieved following bariatric surgery does not remove all perceived barriers to PA, particularly those non-obesity related (e.g. lack of motivation, time and social support).

This study is the first to explore the perceived facilitators to PA following restrictive bariatric surgery and how they differed from participants' pre-surgery perceptions. Weight loss was reported as the most important and only obesity-related perceived facilitator to PA at the post-surgery interview, which was consistent with pre-surgery perceptions. Weight appears to be related to both perceived barriers and facilitators to PA, since at the post-surgery interview participants believed weight loss was a facilitator to PA and excess weight was no longer a barrier to PA. Non-obesity related perceived facilitators identified in the pre-surgery interview were confirmed post-surgery, including social factors (e.g. company to engage in PA) and better time management. A systematic review and meta-analysis found that time management and social support/social change were the most effective behaviour change techniques in changing self-efficacy to engage in PA in people who are obese, and that social support was also effective in changing PA behaviour of people who are obese (75). Since social support and better time management were reported as perceived facilitators to PA both pre- and post-surgery, it is reasonable to expect that strategies aimed at enhancing these factors would facilitate participation in PA.

This study is the first to explore factors perceived as motivators to PA over the first 12 months following restrictive bariatric surgery. Different types of motivations emerged from participants' reports, which can be understood within the context of Self-determination Theory (16, 613). Most participants, regardless of the reported participation in PA, indicated that the main motivators to PA at the post-surgery interview were additional weight loss or maintenance of weight loss, as well as improvement in physical appearance. Specifically, participants explained that additional weight loss or maintenance of weight loss acted as motivators to PA around the 6 months post-surgery, when their weight loss slowed down or plateaued, and the presence of excess skin started to be a concern. These motivators appear to be based on esteem-related factors, which are considered an extrinsic or controlled type of motivation (i.e. dependent on external reward, avoiding a punishment, or attaining approval), and have been shown to have little association with maintenance of PA behaviour (16, 17). Few participants reported that enjoyment of activity was a motivator to PA, which is considered a more intrinsic or autonomous type of motivation (i.e. dependent on the inherent pleasures and satisfactions provided by the activity), and positively associated with maintenance of PA behaviour (16, 17).

Clinical messages

In addition to the comprehensive health benefits of regular participation in PA, there is evidence to suggest that the optimisation of PA, both pre- and post-bariatric surgery, results in better post-surgery outcomes, such as less surgical complications, greater weight loss and maintenance, and favourable changes in body composition and cardiometabolic risk factors (66, 69, 419). However, several studies have reported little or no change in participation in PA post-surgery, with most people failing to achieve international recommendations for the amount of PA required to improve and/or maintain health (4-8). The lack of significant changes in PA might be partially explained by the residual perceived barriers to PA reported in the post-surgery interview, as well as by a lack of appropriate interventions and/or services aimed at helping people who undergo bariatric surgery to engage in PA (222). The knowledge of factors related to PA (i.e. perceived barriers, facilitators, and motivators to PA) is relevant to inform health professionals on the development of successful strategies that target the specific needs of people who undergo bariatric surgery.

The findings of the present study offer a framework for clinicians to discuss and address several of the barriers, facilitators, and motivators to PA in order to optimise PA in people who undergo restrictive bariatric surgery. The first months following bariatric surgery are a period of recovery from the surgical procedure and adaptation to drastic changes in eating habits and body weight (225, 619). According to participants' reports, it appears that they were more receptive and motivated to change their PA around 6 months post-surgery, once the post-surgery adaptation period is over and they felt more able or confident to engage in PA. Given most participants reported an increase in their perceived ability or confidence to engage in PA, strategies aimed at promoting further improvements in people's self-efficacy to engage in PA might have a positive influence on their motivation to PA. Interventions aimed at promoting PA following bariatric surgery could build on the positive changes reported by participants (i.e. positive physical and emotional reactions to PA and mastery of activities) in order to further improve their perceived self-efficacy. For instance, clinicians could provide meaningful positive feedback related to competence or mastery of PA to help people understand their own abilities and skills. Clinicians could also provide opportunities for people who undergo bariatric surgery to engage in modelling experiences, such as observing significant others who have similar physical abilities perform PA. Planning has been reported as an useful strategy to manage goal conflict and improve maintenance of PA behaviour (627). Interventions that aim to optimise action planning (i.e. planning when, where, and how goals will be pursued) and coping planning (i.e. anticipating obstacles and devising coping strategies) may also be beneficial to optimise PA among people who undergo bariatric surgery (623).

Barrier identification and problem solving have been found to be associated with more effective PA behaviour change interventions among people who are obese and the general population (75). It would seem important for clinicians working with people who undergo bariatric surgery to routinely provide information regarding the expected changes (or lack thereof) in perceived barriers to PA. Also, patients could benefit from a multidisciplinary approach that provides strategies to minimise the residual perceived barriers to PA and the new barriers to PA that appear post-surgery. For instance, those people who perceive chronic pain and/or fear of pain as barriers to PA would benefit from optimal pain management and development of coping strategies to deal with PA-related pain and/or fear of pain. Similarly, those people who experience barriers to PA related to excess skin would benefit from advice on preventive strategies for potential skin rashes or infections related to participation in PA. In addition to managing barriers, the identification of perceived facilitators to PA can inform clinicians about people's specific needs in order to provide tailored interventions. Increasing motivation to engage in PA among people who undergo bariatric surgery is needed, given that lack of motivation has been frequently reported as a perceived barrier to PA, both pre- and post-surgery. Specifically, interventions aimed at optimising PA in this population could benefit from focusing on reducing amotivation and promoting more autonomous or intrinsic types of motivation rather than controlled or extrinsic types of motivation (16, 622). Meta-analytic data have supported the positive effects of intrinsic motivation (i.e. when the activity is inherently enjoyable; beneficial for personal goals, values or aspirations) on PA and weight loss (628). Motivational interviewing has been found to reduce resistance and increase motivation to behaviour change, particularly among people who are amotivated (622, 629). A recent meta-analysis has reported that the addition of motivational interviewing to usual care results in increased PA among people with chronic health conditions (630). This approach is often directed at building motivation for a specific behaviour (e.g. PA) by highlighting the benefits and costs of changing versus not changing thereby aiming to resolve the ambivalence between desired and actual behaviour (622).

Strengths and limitations

The present study highlighted the complexity of perceived barriers and facilitators, as well as motivators to PA among people who underwent restrictive bariatric surgery, which included physical, psychological and social factors that were both specific to this population (e.g. concerns about excess skin) and common to the general population (e.g. lack of motivation). The main strength of this study is the longitudinal in-depth exploration (pre- and post-surgery interviews) that provided insight into temporal characteristics of some of the important factors related to participation in PA. Additionally, the focus on people who underwent restrictive bariatric surgery is also a strength, given the lack of in-depth explorations of factors related to PA in this population despite the large increase in the amount of restrictive procedures performed in preference to malabsorptive or mixed procedures. Limitations of this study include a sample of people who attended a private bariatric clinic, which may limit the transferability of the results to people undergoing bariatric surgery in the public health system or of a lower socio-economic status. Also, previous studies have shown that people who are obese, including those who underwent bariatric surgery, often overestimate participation in PA when assessed by subjective methods (e.g. self-report), therefore, it is not clear if the increased participation in PA reported by some participants was real or if the increase in participants' perceived ability to participate in PA was mistakenly understood as an increase in actual participation in PA (5, 401). Future studies should consider the combination of objective methods (e.g. accelerometers) to investigate changes in PA with qualitative exploration of factors related to PA following bariatric surgery. In conclusion, this study provides in-depth information regarding changes in perceived ability to engage in PA, barriers and facilitators to PA, as well as motivators to PA over the first 12 months following restrictive bariatric surgery. These data are relevant to inform the development of tailored interventions to optimise participation in PA in this population.

CHAPTER 7 SUMMARY AND CONCLUSIONS

Overview

This programme of research comprised two studies. Study 1 was quantitative, longitudinal and observational in design, and investigated changes in measures of physical activity (PA), sedentary behaviour (SB), and other health outcomes over the first 12 months following restrictive bariatric surgery. Study 2 was qualitative and longitudinal in design, and explored participants' perceptions of factors related to their participation in PA pre- and post-surgery and how these changed 12 months post-surgery. Although a combined (i.e. mixed-methods) analysis was not possible due to the fact the studies were performed in separate samples, the findings of the two separate studies have provided novel data regarding the effect of restrictive bariatric surgery on objective measures of PA and on factors that are relevant to participation in PA in this population. The findings of both studies, when taken together, can provide clinicians with relevant information to be used in the development of interventions aimed at optimising PA in people who undergo bariatric surgery. This chapter summarises the important and novel findings presented in this thesis and discusses the implications of these findings for clinical practice and future research.

7.1 Restrictive bariatric surgery produces large and significant improvements in several health outcomes, but does not change participation in physical activity or time spent in sedentary behaviour

Findings from Study 1 demonstrated that, when compared with pre-surgery measures, there were no changes in total time spent in PA and SB or in the way PA and SB were accumulated over the first 12 months following restrictive bariatric surgery. Similarly, there was no change in cardiovascular fitness. This lack of change in measures of PA, SB and cardiovascular fitness occurred despite large and significant weight loss, as well as significant improvements in outcomes relevant to participation in PA, such as self-efficacy to exercise, sleep quality and daytime sleepiness. Of note, findings indicated that the significant improvements in measures of HRQoL, obesity-related quality of life, and symptoms of mental health disorders, which had normalised at 12 months post-surgery, did not result in enhanced participation in PA and SB. Both pre-surgery and at multiple time points over the first 12 months post-surgery, participants spent more than 70% of their waking hours in SB, which was mostly accumulated in prolonged uninterrupted bouts ≥ 30 minutes, around 20% of their waking hours in light intensity PA and only 5% of their waking hours in moderate to vigorous (MVPA), which was mostly accumulated in very short bouts < 10 minutes. Further, at 12 months post-surgery, when compared to previous reports for the general population, participants presented lower average daily step count, and greater amount of time spent in SB. This is of importance, as when compared to the general population, people who undergo restrictive bariatric surgery are at a higher risk of the detrimental health effects associated with participation in little PA and increased time in SB. Given restrictive bariatric surgery appears to be insufficient to produce changes in PA.

7.2 Considerations for increasing physical activity prior to bariatric surgery

In accordance with data from Study 1 showing little participation in PA pre-surgery, findings from the sample included in Study 2(A) showed that although most participants believed regular PA was associated with important health benefits, the majority reported they did not engage in sufficient PA to confer such benefits. Most participants also believed that engagement in planned and structured PA (i.e. exercise) or sport was required to be considered physically active and described several barriers to PA, which were both obesity and non-obesity related. Weight loss was identified as the primary facilitator to PA, with other facilitators not related to obesity being reported less commonly (e.g. social support and better time management). Increasing participation in PA in people who are scheduled to undergo bariatric surgery may improve cardiovascular fitness and body composition, reduce surgical complications, enhance post-surgery recovery, and promote greater weight loss and maintenance (50, 69). Understanding barriers and facilitators to PA has been shown to be an integral component of developing behavioural interventions which are effective at producing short-term improvements in objective measures of PA prior to bariatric surgery (34).

In this regard, the findings from Study 2(A) provide a framework for clinicians to discuss and address several of the beliefs, barriers and facilitators to PA in people prior to bariatric surgery. For instance, it would seem important for clinicians working with people who are scheduled to undergo bariatric surgery to challenge their beliefs regarding what PA is and provide educational counselling to this population that PA is not restricted to participation in exercise or sports. This can be achieved by informing them of the health benefits associated with reducing time spent in SB and increasing participation in light intensity PA. The educational counselling could involve strategies to decrease SB by interrupting prolonged periods of sitting time with standing and slow walking. In addition to educational counselling regarding the different types of PA, people who undergo bariatric surgery may also benefit from advice on strategies to overcome the non-obesity related barriers to PA that are not likely to change as a result of the surgery alone, such as time management strategies to assist with participation in PA. As people who are scheduled to undergo bariatric surgery appear to have several perceived barriers to PA and low motivation, it would seem important to promote the use of goal setting strategies that incorporate realistic goals, such as initially targeting achievable increases in time spent in light intensity PA, in combination with regular progression to more challenging activities that can be sustained. Further, participants frequently reported feelings of helplessness and hopelessness regarding their lack of previous success in losing weight with increased participation in PA. Given the potential negative impact of these feelings on people's self-efficacy and perceived value of engaging in PA, a focus on educating people who undergo bariatric surgery on the health benefits related to PA that have been demonstrated in people who are obese in the absence of weight loss, such as reduction in abdominal obesity and cardiometabolic risk factors (618), could be of benefit to increase their motivation. Additionally, providing access to support, from clinicians or friends and family members may contribute to people's participation in PA.

7.3 Considerations for increasing physical activity following bariatric surgery

Study 2(B) demonstrated that, at 12 months following restrictive bariatric surgery, participants reported an increase in their ability to engage in PA. This seems to relate to a greater ease to engage in PA as a result of post-surgery weight loss and consequent reduction in obesity-related perceived barriers to PA. This finding reported in Study 2(B) concurs with data reported in Study 1 showing significant improvements in self-efficacy to exercise, physical and obesity-related quality of life measures, as well as large reductions in weight and weight-related symptoms over the first 12 months post-surgery. However, these favourable changes did not appear to be sufficient to induce a behaviour change of increased participation in PA. The qualitative study revealed that most participants reported not engaging in PA during the first 3 to 6 months post-surgery, and many reported no change or decreased participation in PA over the first 12 months post-surgery. This is consistent with the lack of change in objective measures of PA found in the sample of Study 1, and might explain the association found between decreased number of steps/day and increased weight loss found in this sample. Furthermore, many participants in Study 2(B) reported that there were residual obesity-related barriers to PA, and most participants reported that pre-surgery non-obesity related barriers to PA (e.g. lack of motivation and lack of time) were still present at 12 months post-surgery. Of note, at 12 months post-surgery, most participants reported extrinsic types of motivation, such as additional weight loss and improvement in physical appearance, and few participants reported to be intrinsically motivated by enjoyment of PA. The persistence of barriers to PA and predominance of extrinsic or controlled types of motivation to PA could partially explain the lack of change in PA seen over the first 12 months following restrictive bariatric surgery.

Findings from this programme of research, in combination to current research on health behaviour change models, suggest that behavioural interventions with a multidisciplinary approach are likely required in order to increase participation in PA in this population (540, 604, 610). Furthermore, the combined findings from the studies reported in this thesis indicate that in order to change PA post-surgery, a behavioural intervention which targets goal setting, problem solving, self-efficacy, and motivation to behaviour change is likely to be required (75, 604, 605). Of particular interest to clinicians is the finding that people who undergo restrictive bariatric surgery are more likely to participate in light intensity PA rather than MVPA. Behavioural interventions targeting goal setting may be more successful at promoting PA if there is a focus on initially increasing light intensity PA in place of SB. This may, in turn, promote increased participation in MVPA. This is because encouraging feasible changes and achievable goals is more likely to increase people’s self-efficacy to progress to more challenging activities (75, 608-610). People who undergo restrictive bariatric surgery could also benefit from participation in resistance exercise, in order to prevent the significant loss of fat-free mass found post-surgery. Additionally, since surgery may also result in reductions in measures of bone mineral density, those people who are at risk of or are diagnosed with osteoporosis could benefit from weight-bearing activities. Further, given the lack of change in cardiovascular fitness, people who present with impaired cardiovascular fitness pre-surgery could benefit from participating in a supervised exercise program that could offer improvements in aerobic reserve.

Participants reported that many of the barriers to PA identified pre-surgery, such as pain, self-presentational concerns, lack of motivation, lack of time and social support issues were still present 12 months post-surgery. Therefore, this population could benefit from a multidisciplinary approach that provides information regarding the expected changes (or lack thereof) in perceived barriers to PA and strategies to minimise the residual barriers to PA and the new barriers to PA that may appear post-surgery. For example, optimal pain management and development of coping strategies to deal with PA-related pain and/or fear of pain could be beneficial to those people who perceive chronic pain and/or fear of pain as barriers to PA. Likewise, those people who experience problems related to excess skin would benefit from advice on preventive strategies for potential skin rashes or infections related to participation in PA. The identification of perceived facilitators to PA, such as social support and better time management could also inform interventions that target people’s specific needs. For example, having company to engage in PA (e.g. friend, family member or professional) could be beneficial to people who perceived social support as a facilitator to PA. Of note, lack of motivation to PA was frequently reported as a barrier to PA, both pre- and post-surgery. Thus, there is a clear need for the use of strategies to increase motivation to PA in this population. Specifically, most motivators to PA reported by participants were based on esteem-related factors, which are considered extrinsic types of motivation, and have little association with maintenance of PA (16, 17). Few participants reported intrinsic types of motivation, which are more associated with maintenance of PA. Therefore, it appears that interventions aimed at increasing participation in PA in this population should include strategies to reduce amotivation and promote more intrinsic or autonomous types of motivation rather than extrinsic or controlled types of motivation. For example, motivational interviewing, in addition to usual care, has been found to increase participation in PA among people with chronic health conditions (630). People who undergo bariatric surgery and have low motivation to PA could benefit from a motivational interviewing approach, since this focuses on building motivation for PA by helping people identify the benefits and costs of changing versus not changing, and therefore aiming to resolve the ambivalence between desired and actual behaviour (622).

This programme of research also provided novel information regarding the pattern of change in several outcomes following restrictive bariatric surgery. Study 1 demonstrated that for those outcomes in which surgery produced a significant effect, the majority of change was observed in the first 3 to 6 months, with less, if any change between 6 and 12 months post-surgery. Of note, the pattern of change for those outcomes followed the same pattern of weight loss. Additionally, most participants from Study 2(B) reported they did not find participation in PA needed or desirable during the first 3 to 6 months post-surgery, given the substantial weight loss achieved as a result of the drastic dietary changes. These findings suggest that the best time to introduce interventions aimed at optimising PA may be after the first 3 to 6 months post-surgery, when the majority of weight loss has occurred and participants appeared to be more receptive to engaging in PA.

7.4 Future research directions

This programme of research provided novel and relevant data to inform clinicians of factors relevant to participation in PA prior to and following restrictive bariatric surgery. Future research is needed to draw definite conclusions on differences in the changes in objective measures of PA and SB between those who undergo LSG and LAGB, as well as on associations between weight loss and change in objective measures of PA and SB. Future research is also needed to investigate if a multidisciplinary behavioural intervention aimed at optimising participation in PA in people who underwent bariatric surgery can provide significant and sustained changes in PA. The findings of this thesis suggest such an intervention should include goal setting strategies that target feasible goals for increasing participation in PA, such as an initial increase in light intensity PA, which is likely to enhance people's self-efficacy to progress to an increase in participation in MVPA, as well as promote a reduction in time spent in SB. Additionally, such an intervention should incorporate problem solving and planning strategies to manage the several perceived barriers to PA identified both pre- and post-surgery. Further, the use of strategies that aim to reduce amotivation and promote more intrinsic or autonomous types of motivation appears to be a promising way to enhance participation in PA among people who undergo bariatric surgery. Of note, the investigation of the short and long-term effects of such intervention on other relevant outcomes, such as reduced cardiometabolic risk and weight maintenance is warranted.

Although this programme of research comprised both quantitative and qualitative studies, a combined, mixed-methods approach was not possible as the studies were conducted in different samples. Therefore, our conclusions may be limited by having different samples. For example, although the report of most participants in Study 2(B) indicated a lack of change in PA post-surgery, this could not be confirmed by objective measures of PA. The use of mixed-methods research is recommended, as this would allow for a detailed qualitative exploration of factors underlying differences between people in the degree of change in quantitative measures of PA pre- and post-surgery. This detailed account could provide further understanding to enhance and better target interventions aimed at optimising PA in this population.

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Appendices

Appendix 1

Pre-surgery interview schedule

What does it mean to be physically active?

(*How would you describe a physically active person? What would they need to do to be considered physically active?)*

What do you believe are the benefits of engaging in regular physical activity? *What amount of physical activity is needed for health benefits?*

Is there anything that prevents you or makes it difficult for you to engage in physical activity?

(*Are there any physical difficulties that prevent you from engaging in physical activity? Do you experience any emotional reason that prevents you of engaging in physical activity? Do you experience any social difficulty that prevents you of engaging in physical activity? Do you think there is any environmental factor that prevents you of engaging in physical activity?)*

What do you believe would make it easier for you to engage in physical activity?

Appendix 2

Post-surgery interview schedule

Have there been any changes in your life after the surgery? (*Is there anything you feel hasn't changed? What seem to be the most significant changes?)*

Over the last 12 months, did things happen the way you expected?

Can you remind me of what being physically active means to you?

Over the last 12 months, have there been any changes in your physical activity? (*What type/frequency/duration of physical activity do you currently do? What where the barriers/challenges/obstacles to change? What facilitated the changes?)*

Is there anything that prevents you or makes it difficult for you to engage in physical activity? (*How does this compare to before surgery?*)

What do you believe would make it easier for you to engage in physical activity? (*How does this compare to before surgery?*)

Over the last 12 months, how do you feel when doing physical activity? (*Is it the same or different from before the surgery?*)

How do you feel about yourself when doing physical activity? (*Is it the same or different from before the surgery?*)

Why have you changed (or not) your physical activity? (what motivated you to change?)

What makes you want to do (or not) physical activity?

Appendix 3

Change in total time (minutes/day) spent in sedentary behaviour, light intensity physical activity, and moderate to vigorous intensity physical activity

Assessment time point	n	Observed Mean (SD)	Predicted Mean	Mean change from preceding time point (95%CI)	p-value
Sedentary behaviour (minutes/day)					
Pre-surgery	30	732 (121)	705	---	---
3 months	27	655 (124)	665	-40 (-67 to -14)	0.003
6 months	28	638 (137)	647	-18 (-43 to 8)	0.17
9 months	24	656 (101)	648	1 (-25 to 27)	0.94
12 months	20	661 (99)	664	16 (-14 to 47)	0.29
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				-41 (-86 to 4)	0.07
Light intensity physical activity (minutes/day)					
Pre-surgery	30	209 (97)	195	---	---
3 months	27	208 (90)	211	15 (-7 to 38)	0.17
6 months	28	200 (82)	208	-3 (-24 to 19)	0.80
9 months	24	188 (60)	204	-4 (-26 to 18)	0.74
12 months	20	192 (62)	202	-3 (-28 to 23)	0.83
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				6 (-31 to 44)	0.73
Moderate to vigorous intensity physical activity (minutes/day)					
Pre-surgery	30	54 (33)	51	---	---
3 months	27	51 (35)	53	2 (-10 to 14)	0.71
6 months	28	63 (54)	64	10 (-1 to 22)	0.08
9 months	24	59 (48)	66	3 (-9 to 15)	0.65
12 months	20	54 (24)	55	-11 (-25 to 2)	0.09
				Mean change (95%CI)	**p-value**
Pre-surgery to 12 months				4 (-16 to 23)	0.71

Abbreviations: CI: confidence interval; SD: standard deviation. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point using all available information (i.e. using only those cases observed at that time point [observed mean] and including cases missing in that time point [predicted mean]) and only data from participants who met the minimal monitor wear requirements were included in the analyses (see section 3.1.5.2.2 for definition of minimal monitor wear requirements).

Appendix 4

Change in total time (percentage of waking hours) spent in sedentary behaviour, light intensity physical activity, and moderate to vigorous intensity physical activity according to surgery type

Assessment time point	n	Predicted Mean		Mean change from preceding time point		Difference in mean change between LSG and LAGB (95%CI)	p-value
		LSG	LAGB	LSG	LAGB		
Sedentary behaviour (% of waking hours)							
Pre-surgery	30	72	78	---	---	---	---
3 months	27	69	78	-3	0	-3 (-9 to 3)	0.27
6 months	28	68	76	-1	-2	1 (-4 to 7)	0.66
9 months	24	69	76	0	0	0 (-6 to 6)	0.91
12 months	20	71	76	2	1	1 (-6 to 8)	0.73
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				-2	-2	0 (-10 to 10)	0.94
Light intensity physical activity (% of waking hours)							
Pre-surgery	30	22	17	---	---	---	---
3 months	27	25	18	3	0	3 (-2 to 8)	0.29
6 months	28	24	19	-1	1	-2 (-7 to 3)	0.48
9 months	24	24	18	-1	-1	0 (-5 to 5)	1.00
12 months	20	23	18	0	0	0 (-6 to 6)	0.92
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				1	1	1 (-8 to 8)	0.89
Moderate to vigorous physical activity (% of waking hours)							
Pre-surgery	30	6	5	---	---	---	---
3 months	27	6	5	1	0	1 (-2 to 3)	0.69
6 months	28	7	5	1	1	1 (-2 to 3)	0.71
9 months	24	8	6	0	1	0 (-3 to 3)	0.89
12 months	20	6	8	-2	-1	-1 (-4 to 3)	0.68
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				1	0	0 (-4 to 5)	0.93

Abbreviations: CI: confidence interval. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point including cases missing in that time point [predicted mean]) and only data from participants who met the minimal monitor wear requirements were included in the analyses (see section 3.1.5.2.2 for definition of minimal monitor wear requirements).

Change in total time (minutes/day) spent in sedentary behaviour, light intensity physical activity, and moderate to vigorous intensity physical activity according to surgery type

Assessment time point	n	Predicted Mean		Mean change from preceding time point		Difference in mean change between LSG and LAGB (95%CI)	p-value
		LSG	LAGB	LSG	LAGB		
Sedentary behaviour (minutes/day)							
Pre-surgery	30	696	731	---	---	---	---
3 months	27	645	715	-50	-16	-34 (-89 to 21)	0.22
6 months	28	628	697	-17	-18	1 (-54 to 56)	0.97
9 months	24	630	695	2	-1	4 (-56 to 64)	0.90
12 months	20	648	707	18	12	6 (-60 to 72)	0.86
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				-48	-25	-23 (-120 to 74)	0.63
Light intensity physical activity (minutes/day)							
Pre-surgery	30	209	158	---	---	---	---
3 months	27	229	164	20	6	14 (-33 to 61)	0.55
6 months	28	221	174	-8	10	-18 (-65 to 29)	0.45
9 months	24	217	168	-4	-5	2 (-49 to 52)	0.94
12 months	20	215	167	-2	-2	-1 (-57 to 55)	0.98
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				6	9	-3 (-82 to 77)	0.94
Moderate to vigorous physical activity (minutes/day)							
Pre-surgery	30	53	45	---	---	---	---
3 months	27	56	45	3	0	3 (-22 to 29)	0.79
6 months	28	69	50	13	5	7 (-18 to 33)	0.58
9 months	24	70	56	1	6	-5 (-32 to 23)	0.73
12 months	20	57	48	-13	-8	-5 (-35 to 25)	0.74
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				4	3	1 (-41 to 43)	0.97

Abbreviations: CI: confidence interval. All comparisons done using multilevel mixed-effects linear regression model. At each assessment time point, data were presented as the estimate for each time point including cases missing in that time point [predicted mean]) and only data from participants who met the minimal monitor wear requirements were included in the analyses (see section 3.1.5.2.2 for definition of minimal monitor wear requirements).

Appendix 5

Estimated pre- to 12 months post-surgery change in measures of physical activity and sedentary behaviour with a 10% increase in percentage weight loss

	n	Estimate	95% CI	p-value
Daily step count (steps/day)				
Unadjusted	21	-1993	-3188 to -798	0.002
Adjusted for type of surgery	21	-2309	-3738 to -880	0.003
Light intensity physical activity (min/day)				
Unadjusted	20	-2	-32 to 28	0.89
Adjusted for type of surgery	20	10	-35 to 54	0.65
Moderate to vigorous intensity physical activity (min/day)				
Unadjusted	20	1	-7 to 10	0.73
Adjusted for type of surgery	20	1	-11 to 14	0.81
Sedentary behaviour (min/day)				
Unadjusted	20	-29	-77 to 20	0.22
Adjusted for type of surgery	20	-5	-76 to 66	0.88

Abbreviation: CI: confidence interval.

Appendix 6

Accumulation of sedentary behaviour in uninterrupted bouts < 10 minutes and of moderate to vigorous physical activity in bouts ≥ 10 minutes

Assessment time point	n	SB (% of total SB in bouts < 10 minutes) Mean (SD)	MVPA (% of total MVPA in bouts ≥10 minutes) Mean (SD)
Pre-surgery	30	20 (11)	12 (14)
3 months	27	20 (10)	12 (15)
6 months	28	22 (11)	14 (14)
9 months	24	21 (9)	18 (15)
12 months	20	20 (10)	14 (14)

Abbreviations: MVPA: moderate to vigorous physical activity; SB: sedentary behaviour. At each assessment time point, only data from participants who met the minimal monitor wear requirements were included in the analyses (see section 3.1.5.2.2 for definition of minimal monitor wear requirements).

Appendix 7

Change in daily step count according to surgery type

Assessment time point	n	Predicted Mean		Mean change from preceding time point		Difference in mean change between LSG and LAGB (95%CI)	p-value
		LSG	LAGB	LSG	LAGB		
				Daily step count (steps/day)			
Pre-surgery	29	8455	6952	---	---	---	---
3 months	27	8641	8400	186	1448	-1262 (-3347 to 823)	0.23
6 months	26	9154	8754	513	354	159 (-1942 to 2260)	0.88
9 months	26	9071	9397	-83	643	-726 (-2842 to 1390)	0.50
12 months	22	8788	8880	-283	-517	234 (-2028 to 2495)	0.84
				Mean change		**Difference in mean change (95% CI)**	**p-value**
Pre-surgery to 12 months				333	1929	-1596 (-4900 to 1708)	0.34

Abbreviation: CI: confidence interval.

Appendix 8

Summary of descriptive statistics for secondary outcomes according to surgery type

Cardiovascular fitness (Physical Working Capacity 170 test [Watts])

Assessment time point	n	Observed Mean (Standard deviation)	
		LSG	LAGB
Pre-surgery	24	191 (64)	198 (74)
12 months	16	205 (54)	223 (48)

Self-efficacy to exercise (Exercise Self-Efficacy Scale score)

Assessment time point	n	Observed Mean (Standard deviation)	
		LSG	LAGB
Pre-surgery	30	55.7 (16.4)	46.8 (18.8)
3 months	30	67.8 (19.8)	65.5 (18.1)
6 months	29	71.5 (16.5)	70.9 (12.1)
9 months	29	70.2 (15.7)	72.6 (12.9)
12 months	28	73.4 (17.1)	69.3 (21.8)

Sleep quality (Pittsburgh Sleep Quality Index score)

Assessment time point	n	Observed Mean (Standard deviation)	
		LSG	LAGB
Pre-surgery	30	8.5 (2.9)	9.1 (2.7)
3 months	30	6.2 (3.8)	6.2 (2.7)
6 months	29	5.3 (3.9)	5.8 (4.1)
9 months	29	4.9 (3.5)	4.3 (2.5)
12 months	28	5.4 (3.8)	6.2 (2.6)

Daytime sleepiness (Epworth Sleepiness Scale score)

Assessment time point	n	Observed Mean (Standard deviation)	
		LSG	LAGB
Pre-surgery	30	8.2 (4.1)	9.2 (6.0)
3 months	30	5.4(3.8)	6.8 (5.7)
6 months	29	4.6 (3.9)	5.7 (3.4)
9 months	29	4.7 (4.6)	6.7 (4.4)
12 months	28	4.7 (3.2)	6.8 (4.5)

Body composition (DXA)

Assessment time point	n	Observed Mean (Standard deviation)	
		LSG	LAGB
Fat mass (kg)			
Pre-surgery	28	53.8 (9.8)	61.0 (10.3)
12 months	26	28.5 (7.0)	48.1 (13.1)
Fat mass (%)			
Pre-surgery	28	49 (5)	52 (6)
12 months	26	36 (6)	46 (9)
Fat-free mass (kg)			
Pre-surgery	28	58.0 (9.3)	60.2 (12.6)
12 months	26	52.7(8.5)	58.2 (11.3)
Fat-free mass (%)			
Pre-surgery	28	52 (5)	49 (5)
12 months	26	65 (6)	54 (9)

Bone mineral density (DXA)

Assessment time point	n	Observed Mean (Standard deviation)	
		LSG	LAGB
Total body (g/cm^2)			
Pre-surgery	28	1.26 (0.12)	1.23 (0.11)
12 months	26	1.27 (0.13)	1.22 (0.09)
Total body T-score			
Pre-surgery	28	1.54 (1.10)	1.11 (0.79)
12 months	26	1.52 (1.26)	1.00 (0.95)
Spine (g/cm^2)			
Pre-surgery	28	1.32 (0.14)	1.31 (0.13)
12 months	26	1.24 (0.18)	1.26 (0.17)
Pelvis (g/cm^2)			
Pre-surgery	28	1.14 (0.17)	1.06 (0.13)
12 months	26	1.09 (0.15)	1.04 (0.14)

Health-related quality of life (SF-12v2)

Assessment time point	n	Observed Mean (Standard deviation)	
		LSG	LAGB
Physical health-related quality of life (PCS score of the SF-12v2)			
Pre-surgery	30	43.3 (7.8)	42.8 (8.7)
3 months	30	53.9 (5.6)	48.6 (9.2)
6 months	29	53.6 (9.6)	46.6 (8.8)
9 months	29	54.7 (5.3)	52.9 (7.3)
12 months	28	56.5 (6.1)	51.9 (6.2)
Mental health-related quality of life (MCS score of the SF-12v2)			
Pre-surgery	30	47.3 (10.5)	46.3 (8.3)
3 months	30	52.1 (8.6)	52.4 (7.0)
6 months	29	50.8 (10.1)	51.7 (7.3)
9 months	29	50.3 (9.6)	50.6 (11.4)
12 months	28	51.0 (10.2)	50.1 (7.7)

Obesity-related quality of life and weight-related symptoms

Assessment time point	n	Observed Mean (Standard deviation)	
		LSG	LAGB
Total score of the IWQOL_Lite			
Pre-surgery	30	56.2 (17.3)	56.2 (10.4)
3 months	30	82.0 (20.9)	72.7 (15.1)
6 months	29	86.9 (18.3)	77.5 (14.6)
9 months	29	91.7 (13.2)	82.1 (9.7)
12 months	28	91.8 (13.8)	85.5 (9.9)
Obesity-related quality of life (OWLQOL score)			
Pre-surgery	30	38.0 (18.0)	39.7 (14.8)
3 months	30	71.6 (24.0)	60.9 (22.9)
6 months	29	81.8 (19.2)	62.0 (19.6)
9 months	29	86.1 (15.6)	67.0 (15.8)
12 months	28	85.2 (18.8)	71.4 (16.3)
Weight-related symptoms (WRSM score)			
Pre-surgery	30	32.1 (17.4)	36.6 (15.2)
3 months	30	13.8 (12.4)	22.7 (20.0)
6 months	29	9.4 (9.2)	16.6 (14.7)
9 months	29	9.0 (7.8)	18.1 (19.3)
12 months	28	8.2 (8.6)	13.1 (13.1)

Abbreviations: IWQOL-Lite: short version of the Impact of Weight on Quality of Life Questionnaire; OWLQOL: Obesity and Weight-loss Quality-of-life Instrument; WRSM: Weight-related Symptoms Measure.

Mental Health (Beck Depression Inventory score)

Assessment time point	n	Observed Mean (SD)	
		LSG	LAGB
Symptoms of depression			
Pre-surgery	30	13.4 (8.2)	9.5 (4.4)
3 months	30	6.8 (6.8)	6.0 (2.0)
6 months	29	6.5 (7.5)	5.5 (4.0)
9 months	29	5.3 (6.7)	4.0 (3.4)
12 months	28	5.1 (6.1)	3.5 (2.9)

Mental Health (Depression, Anxiety and Stress Scales)

Assessment time point	n	Observed Median [Interquartile range]	
		LSG	LAGB
Symptoms of depression (depression subscale of the DASS-21)			
Pre-surgery	30	2.0 [0 – 10]	4.0 [2.5 – 6.5]
3 months	30	1.0 [0 – 3.0]	1.0 [1.0 – 2.0]
6 months	29	1.0 [0 – 4.0]	2.5 [1.5 – 3.5]
9 months	29	1.0 [0 – 5.0]	5.0 [0 – 2.5]
12 months	28	0 [0 – 4.0]	1.5 [0.5 – 4.5]
Symptoms of anxiety (anxiety subscale of the DASS-21)			
Pre-surgery	30	2.0 [1.0 – 6.0]	3.5 [2.0 – 6.0]
3 months	30	1.0 [0 – 2.0]	1.0 [1.0 – 2.5]
6 months	29	1.0 [0 – 2.0]	1.0 [1.0 – 2.0]
9 months	29	1.0 [0 – 2.0]	1.0 [0.5 – 2.0]
12 months	28	0 [0 – 2.0]	1.5 [0.5 – 3.5]
Symptoms of stress (stress subscale of the DASS-21)			
Pre-surgery	30	6.0 [3.0 – 10.0]	5.5 [3.5 – 10.0]
3 months	30	4.5 [1.0 – 7.0]	6.0 [2.0 – 7.0]
6 months	29	3.0 [0 – 5.0]	5.5 [1.5 – 8.5]
9 months	29	2.0 [0 – 6.0]	2.5 [1.0 – 6.5]
12 months	28	4.0 [0.5 – 6.0]	5.0 [2.0 – 7.0]

Abbreviation: DASS-21: Depression, Anxiety and Stress Scales.

Appendix 9

Additional supporting quotes for emergent themes in the pre-surgery interview

Beliefs about physical activity	
Comprehensive benefits	'I would assume as a physical active person, you know … your muscle tone is better.' (P15) 'Well you're fitter, and you can do more.' (P15) 'It makes you healthier, because then you don't have excess weight on you.' (P13) 'You know, give your body the best chance not to get diseases down the track.' (P3) 'Yeah, I think it can prevent, sort of things like depression and that sort of thing and also helps the heart and lungs, and all your bodily functions are a lot better off with regular physical activity, I believe.' (P16)
Perceived barriers to physical activity	
Obesity-related perceived barriers to physical activity	
Physical barriers	'I do suffer from a lot, a lot of back pain. And then I obviously I have neck issues as well.' (P5)
Self-presentational concerns	'I don't like to see myself do that so why would anyone else?' (P14) 'Ah no…yeah, self-consciousness, self-consciousness, there is no way I'd set foot into a gym, a public gym umm…not at my size that I am now, I wouldn't do it umm…I suppose you are embarrassed, I suppose…you know…I suppose so…and most people in the gym are fairly fit and active you know, I can't run.' (P19)
Non-obesity-related residual perceived barriers to physical activity	
Lack of motivation	'Maybe it is a motivation thing, because if I was truly, truly motivated, I would find the time in there (to do PA).' (P11) 'Oh can't be bothered going for a walk, I'll do it later, or tomorrow, or never.' (P16)
Lack of time	'But I have no desire at the moment to get up at five in the morning because of all the other things that are happening. So, for me, it is, the main issue at the moment is that I'm working too much.' (P11) 'Three kids! three kids…take them through about 8, 8:30 in the evening and then you have to clean the house, that takes you through about 9, 9:30 and then is finally some time with

	my wife and actually having some you know, us time…so down time it's just not much…umm…very little.' (P2)
Lifestyle	'Not a lot, catch up on sleep, (laughs) that's about it. I don't, I don't do a lot.' (P13) 'There is no doubt I can get up and walk and that, is just I don't prioritise' (P18)
Perceived facilitators to physical activity	
Obesity-related perceived facilitator to physical activity	
Weight loss	'Losing weight would help me motivate myself.' (P13) 'Losing weight, losing weight is number one. Because, umm, I know I can … I will be healthier and more energetic and probably with that a bit more … you know, with that feeling of having more energy, I will be more motivated to go out and do some exercise.' (P16)
Non-obesity related perceived facilitators to physical activity	
Social factors	'I have my best success when I had a friend of mine help me stay motivated in the gym, he would turn up in the morning, half past five and beep his horn until I get out of bed and join him, he would drive me around to the gym and so forth so, I had someone who was forcing me to do stuff and who I was letting down if I didn't do stuff and that had a massive impact in terms of sticking with stuff, especially in that first two months window, you know where is pretty easy to sort of go oh, I'm not going there today, I'm a bit sore, not gonna do it. So having someone going come on, get in the car, let's go, it was definitely a benefit.' (P2)

Appendix 10

Additional supporting quotes for emergent themes in the post-surgery interview

Changes in reported participation in physical activity	
No participation in physical activity in the first months following surgery	'So basically, for I would say three months, I did no personal training. I did nothing. And then probably about two and a half months in, I did start just short walks and stuff. And then I did go back to personal training and I did light stuff, just to get myself there.' (P6) 'I just still didn't feel that I needed to (engage in PA in the first few months after surgery), you know what I mean?' (P13)
Increased participation in physical activity	'I consciously, when the opportunity arises, try and walk a bit further and during the day at work now I find I get up and I go for a walk around the yard and things like that, and interact with people a bit more, whereas before I was quite comfortable to sit in my office for a period of time. I tend to now park further away from the shopping centre front door to make myself walk. So I consciously don't look for the closest car park anymore. I look for the farthest.' (P19) 'Yeah, it's just leisure time rather than actually planned activity. As far as also with the kids, and getting out on a weekend, instead of just sitting around the house and doing nothing. It's easier to get out and take them out places and go to the park or do an activity with them.' (P2) 'Well, it's certainly not perfect, but I'm doing more. I'm getting out. I'm feeling better about it. The dogs are benefitting from it. They've lost weight too. [laughs] I actually have a post office box in the city. I don't get my mail delivered to my home address because I want to go for that 15, 20 minute walk during the day to get out of the office, to get some fresh air.' (P11)
No change or decreased participation in physical activity	'I'd like to be more active. Before, I did lots of … I was at the gym and I'd go rock climbing and lots of sports and swimming and walking. And I've always been lazy, but I did that before, because I knew I had to at least make an effort and try and lose weight.' (P14) 'The walk I'm walking faster. The physical activity on the walk, it's better. The number of times I'm doing it, not so much. The fact that it's easier isn't meaning that I'm doing it more, which I thought it probably would. I'm still doing the once-a-week Pilates physio, which is good.' (P15)
Changes in perceived ability to participate in physical activity	

Physical activity was easier	'It's different. Normal physical activity is easy now, easy for me, like physically, so that's not a problem' (P3)
Improvement in perceived ability to engage in physical activity	'I feel like I can do a lot more, and I feel lighter. I feel like before, as I said, I felt like an old lady, so I felt like there were a lot of things I couldn't do, certain exercises and what not.' (P17) 'Now, I feel younger and healthier in that I still have moments where I'm like, "Wow, I can't believe I can do that now, I can't believe my body is capable of those things." Like I said, walking to the top of that temple, or doing a certain pose in yoga, I'm like, "Wow, I can do this stuff".' (P17) 'I mean, I think the physical component is a huge factor that my attitude about what I'm capable of and what I can do has changed so much that if someone said … my friend has always wanted me to do City to Surf or one of the fun runs they have during the year, and I've always thought, "There's no way I want to go on a run with a bunch of healthy people and be the last person across the line and struggle and be in pain." Whereas now I go, "Yes, I can do that," and that's because my mental outlook, I guess, has changed.' (P17) 'Also, I do Pilates physio once a week. The improvement – as I lost the weight, I could feel physical strength. The squats were able to be deeper. Stretches were easier. Yeah. And more range, a lot more range. I've been doing that for three years, and in the last 12 months the improvement feels like it's three times – it's probably not, but it feels like it is three times. I can step up onto a platform that's the equivalent of three regular steps, which I couldn't do before. I didn't have the lift in my knees.' (P15) 'Particularly in America we travelled with a couple who's a bit older than us but they're active. But it surprised me that they were tired. And they are older, but I'd considered them quite fit, but I had more energy than they did. That kind of felt good, not that I felt like I was better than them, but it felt good for me because I don't think that would've been the case before the surgery. I think I'd have been the one who got tired first.' (P15) 'As I said before, like climbing up and down rocks with confidence, walking a lot further than I used to. My wife used to lead the way. Now it's me leading the way and her saying, "Can you wait for me?".' (P19) 'It's not a hassle anymore. It's not a hassle. It's not a hassle. [laughs] I just didn't feel like it (doing PA) … yeah, now for me it's just not a hassle to get up and just go out, walk to a friend's house instead of getting in the car.' (P7)

Changes in perceived barriers to physical activity	
Physical barriers	‘Yeah, well before, I was basically taking pain medication every day when I got home from work, because I'd have a really sore lower back. I used to get like a sort of sciatic type pain down the back of my legs. I'd often be like limping around at work, and that basically never happens anymore.’ (P17) ‘Because at work, I’ve got to walk upstairs to get to the staff room. Before that, my knee used to click, but it doesn’t anymore. Prior to my surgery, yeah. There’s no pain in my legs anymore. Before the surgery, there was pain in my back. But now there’s no pain as such, because of the weight.’ (P9) I just think that because my body’s changed so much, and it is so much easier – I don’t have sore feet, I don’t have a sore knee. Do you know what I mean? It’s just easier. I just think it’s easier when you don’t have the excess weight on.’ (P6) ‘It’s obviously with my knee reconstruction, the damage I had to my left knee, that's been fantastic as well because losing the weight has taken the pressure off my joints so I don’t have that constant pain. I don’t have to live with that so I’m really very comfortable with how all that's turned out.’ (P19) ‘Part of it's also just when you're big and unhealthy you don't want to move. You don't want to run around and place strain and stress on your knees and shoulders and so forth. So having lost the weight, those sort of barriers are definitely a lot less, and I'm more inclined to do stuff. Whereas before I was more inclined to not do stuff. Now, it's actually a conscious sort of thing. In the past I would think “Oh, I don't know that I could do that,” because I was worried about being unfit and not being able to last very long, playing with the kids and so forth. Whereas that's no longer a conscious decision – it's just whether I want to do it or not.’ (P2) ‘I mean getting out on the bike and so forth; it's a lot less of a struggle. It's a lot better feeling of doing something rather than … I don't know how to put it in words. In the past when I was riding the bike before the surgery, you felt lethargic. You felt sort of heavy. Mentally you just feel heavy.’ (P2) ‘Yeah, just having the energy to do it. Before I just couldn’t do it. Just being so big, and I would just go walking for 10 minutes and be breathless. Now, I can just do it without even thinking of it, and thinking, “Oh, my God. I’m going to be breathless.” But now, I just do it.’ (P9)

	'Just before, I just didn't want to walk because I would get so breathless very quickly. But, now, I know I can do it and just keep going. I feel really good about it.' (P9) 'We've got this big hill where I work. It's massive. It's on a really big gradient. And I used to get sore knees and be puffing when I used to get to the top of the hill to work. And probably embarrassing if anyone was behind me. Now, not even puffing at all. I could run down again, back up again. So that was nice.' (P14) 'Yeah. It used to, like getting in and out of cars and things, it used to be hard, strained. My health, my heart doesn't feel like it's palpitating and things like that. I generally feel healthier.' (P3) 'So you know, even if it's something as simple as just going for a walk and so forth, instead of worrying about is your heart rate going too much, are you out of breath, and so forth, you can walk and just enjoy the walk. Whereas in the past, it was more about how do you feel in that situation.' (P2)
Self-presentational concerns	'Now, I go to a yoga class that's run by a yoga instructor, not a physiotherapist. It's a big class, and I don't feel self-conscious about being in the class or anything, and I really enjoy it.' (P17) 'I can get clothes on. It's no bloody hassle to get out the front door. I just put on a pair of pants and a T-shirt and off I go whereas before it was like, "What am I going to wear? What fits me?" The confidence to … being scared to walk on the street and people look at you because you just look revolting or I felt revolting, and now you just feel unreal.' (P7) 'I don't get stared at anymore [chuckles] when you go walking or in shops. Because when you're obese, you know people are looking at you. You know what they're thinking. But that doesn't happen anymore, so it's really good.' (P9) 'I had very low self-esteem. I always knew that whenever someone looked at me, I would be judged because of my body image, but now it doesn't have that effect on me anymore. In myself, I always thought that I wasn't good enough for people. I always put myself in a lower level. I think it's definitely a confidence barrier again. That I'm not scared of being the way I am now as before I was, and then the insecurities and stuff like that. Now, I just don't care what people think of me.' (P13) 'Maybe my confidence … I've always been confident, but it's gone up a little bit, I would say. Yeah, yeah. I was

	always confident before, but I always mindful that people might be looking at me because I'm a bigger person. Now I don't feel like they're looking at me, I'm just … yeah. It's more about perception.' (P14)
Improvement in wellbeing and vitality	'I feel happier, I've got more energy, and obviously I've seen results, so you feel better in yourself once you've lost weight and you're fitting into clothes that you haven't fitted into for quite some time. So it's obviously the band is helping me a lot with my eating, so I eat smaller portions, I'm eating the right foods, and yeah, I feel healthy, I feel good.' (P5) 'Well, I've lost 20 kilos, and I feel 100% better than I did before, and I … yeah, just in everything, in my health and just in my wellbeing as well. I feel healthier.' (P3) 'Obviously the physical changes, and I'm much more healthier than I was. What makes me feel healthier? Just the amount of exercise, I suppose, that I can do now. I never would ever think that I would go jogging, but I go jogging now, and stuff like that.' (P6)
Residual perceived barriers to physical activity	
Residual obesity-related perceived barriers to physical activity	
Physical barriers	'I still do, but not as severe, because before the surgery, because of the extra weight, I used to have severe migraines, but I haven't had too many. I've been pretty good since I've lost the weight. I mean I've got scoliosis and my back is bad, so I have those days every now and then, that it's sore, but nowhere near as bad as it used to be when I had the extra weight on.' (P5) 'I'm going through a lot of pain and stuff in my back and kidneys and all those sorts of things so I'm getting acupuncture which is probably the best thing that I've ever … I'm bouncing off the walls with that. It's just fantastic and it's also training my pelvic floor which was really weak because I was so big. If you know what I mean, I was really weak there and my lower back was really sore and stuff. And it's like the surgeon said, you know, he said, "You thought that was all going to go." And I was like, "Yeah." But it's not, because you've been working, you've been walking around in a certain way for so many years but now that you're lighter, the pain is still there.' (P7)
Self-presentational concerns	'And then, the pool's opening soon. So I'm looking forward to that opening, but still I think, "No, I need to lose weight before I go to the pool. I'm embarrassed the way I look. I look like I do going to the pool, blah, blah, blah".' (P16) 'Having lost the weight, and even now, I'm a lot less self-conscious and a lot more willing to put myself in situations where I'll be doing something or go to do something, because I just look and feel better. So mentally, I don't put

	that roadblock between myself and think, "Oh, what if someone looks at me funny," or whatever it is. But there's times, mental-wise, everyone still has those days when it doesn't quite … the planets don't quite align and you think the worst of yourself.' (P2) 'Before, the way I felt about my body was overwhelming. It's all I thought about, whereas now it's something that only really bothers me when I really think about it. Do you know what I mean? Yeah, so I mean, that hasn't changed. I still need to work on my body image, but it's not as bad as it used to be.' (P17)
Residual non-obesity related perceived barriers to physical activity	
Lack of motivation	'Yeah. I'm not hugely self-motivated. I have to make a concentrated effort to do that and that's been me, like through life. Even when I was involved in sport ... if I do something I do it at 100% but I don't always do it for a long period of time. When I played football, my lack of dedication, I suppose, and commitment for a long period of time limited my career, I suppose. That's just me.' (P19)
Lack of time	'Only really like … I work full time and I'm a shift-worker, and I also am a University student as well, part time. The only barriers I have now, is that sometimes I feel a bit time poor, like during exam week for example. I think that's a pretty normal or a pretty common barrier with a lot of people regardless of their weight or their fitness level' (P17) 'Oh, I've done a few of the aqua-aerobics kind of classes and stuff, but for that you have to drive a fair distance. For me, we don't have a pool that's five minutes away. I just found that by the time that you leave the house and you get back to the house is a two-hour period. And two hours is a lot … it's just too much, really, when I'm trying to fit in work and the kids. I have done a few bits and pieces of that, but it's just time, for me, for that.' (P6) 'Oh, time. Actually, making time.' (P11)
Social support issues	'If I had someone coming in every day, cooking my meals and telling me to get off the couch and go exercising, and keeping me accountable, I think I'd be a lot better. I would love that. If I didn't have to cook meals, and if I had someone that was making me go out and exercise, that would be really good. I'd love that. But of course, who has that? Other than a celebrity …[laughter]…and I could not afford that ever, but even someone that could do that for three weeks, and get me started, and I'd see the results.' (P16)
Residual perceived facilitators to physical activity	
Residual obesity-related facilitator to physical activity	
Weight loss	'Being lighter. Being lighter, for God's sake. [laughs] Yeah, absolutely, just being lighter and just feeling great, and

	people telling you, you look great. Far out, that is unreal.' (P7) 'I guess if you have more energy (after losing weight) … if you get up and you feel good you feel more that you want to go and do exercise.' (P5) 'I just think that because my body's changed so much, and it is so much easier – I don't have sore feet, I don't have a sore knee. Do you know what I mean? It's just easier.' (P6)
Perceived motivators to physical activity	
Body weight and appearance	'And I felt better and was losing weight, so it probably just clicked into my mind that it's not eating much plus exercise equals skinnier and healthier. So something clicked, I suppose.' (P3) 'Then when the weight loss slows down, and you reach a comfortable point, you think, "Okay, well where am I now, and where do I want to be?" You think, "I just want to be healthy, and get the best out of my body that I can." That's when your attitude changes. I'm hoping that it'll help improve my body image, rather than seeing the loose skin and stuff. I think if I feel physically fit and healthy, or muscular, or whatever I think that it might help my body image as well.' (P17) 'Fitness and that last 15 kilos. It is a little bit about weight loss, but it's mostly about fitness and health. Yeah, so fitness, to me, is being able to tolerate aerobic exercise where I'm getting my heart rate up. I want to be someone that actually enjoys that, and I'm getting that way, yeah.' (P17)
Social interaction	'So I guess it's the interest in … and walking the dog – the dog likes it, so you feel that's a nice experience for you both, because you've made the dog happy, and also as a dog owner you have a responsibility to put the dog to get some exercise.' (P15)
Enjoyment of activity	'I think it's just a nice feeling to get out there, especially when the air is crisp and you feel that on your face. I like that feeling. It is a little bit of a stress reliever as well. You actually do unwind a bit more, yeah.' (P11) 'Getting out in the fresh air. Getting out of the house, and getting fresh air and just wanting to get active.' (P9) 'I don't consciously think about it. I do what I do and I do it because I enjoy it. I think the main thing is I'm not frightened to have a go at something whereas before I would avoid it. I would avoid going to the beach and swimming and things like that, whereas now I actually … if I want to do that, I'll go and do it and that comes about through that confidence, I suppose. I'm less introverted and wanting to be out and about. I actually want to get out and

	do things but I want to get out and do things at a leisurely pace. I'm not into sort of power walking and things like that, but if we had to go to a waterfall or something out in the bush or whatever, I'm quite happy to walk at my pace and go and do those things.' (P19)