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Predictors of physical activity after gastric bypass - A prospective study

Running title: Physical activity after gastric bypass

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Authors' contributions

IKL, FFS and IB designed the study. TM, IKL and IB were involved in the data collection. IB, ILK and BHH performed the statistical analyses and IB drafted the manuscript. All authors contributed to the interpretation of the analyses and revisions of

the manuscript. All authors have read and approved the final manuscript.

Conflict of Interest

The authors declare that they have no conflict of interests.

Key words: Physical activity; bariatric surgery; gastric bypass; self-regulation: psychological; accelerometer; behavior change

Abstract

Background

Most patients do not meet the recommended level of physical activity after bariatric surgery, and psychological factors underlying postoperative physical activity remain poorly understood. This study aimed at identifying self-regulatory predictors of physical activity after bariatric surgery.

Methods

Questionnaire data including self-regulation variables and the short-version of the International Physical Activity Questionnaire (IPAQ-SF) were obtained in a prospective cohort of 230 patients one year after Roux-en-Y Gastric Bypass. The study sample consisted of participants consenting to wear an ActiGraph GT3X+ accelerometer for seven consecutive days 18–24 months after surgery (n=120).

Results

A total of 112 participants with complete self-report data provided valid accelerometer data. Mean age was 46.8 years (SD=9.3), 81.3% was women. Pre-and postoperative BMI was 44.8±5.5 kg/m^2 and 30.6±5.0 kg/m^2, respectively. Total weight loss was 28.9% (SD=7.5). By objective measures, 17.9% of the participants met the recommended level of moderate-to-vigorous-intensity of physical activity of ≥150-min/week, whereas 80.2% met the recommended level according to self-reported measures. Being single, higher education level, and greater self-regulation predicted objective physical activity in

multivariate regression analysis. Greater self-regulation also predicted self-reported physical activity. Weight loss one year after surgery was not associated with self-reported or objectively measured physical activity.

Conclusions

Despite large differences between accelerometer-based and subjective estimates of physical activity, the associations of self-regulatory factors and weight loss with postoperative physical activity did not vary depending on mode of measurement. Self-regulation predicted both objective and self-reported physical activity. Targeting patients' self-regulatory ability may enhance physical activity after gastric bypass.

Introduction

Regular physical activity is recommend to improve weight loss maintenance and health outcomes after bariatric surgery [1, 2]. Norwegian national guidelines recommend physical activity (PA) of moderate intensity for a minimum of 150 min/week, or vigorous intensity for a minimum of 75 min/week performed in bouts of at least 10 minutes [3], coinciding with public health guidelines in the UK and US [4, 5]. Recent studies have shown that the majority of patients do not meet the recommended level of PA postoperatively [6]. Indeed, most patients make modest postoperative changes to their preoperative PA levels at best [7-9]. Some even decrease their activity levels [8]. It has been suggested that psychological factors are important for long-term weight management through affecting the patients' ability to adjust their behavior postoperatively [10]. However, factors underlying postoperative PA remain poorly understood [11] and whether associations of psychological factors and weight loss with PA differ by mode of measurement has to our knowledge not been described in bariatric populations. Identifying predictors of postoperative PA could contribute to the development of more effective interventions for enhanced activity levels after surgery.

Self-regulation is essential for adopting new or maintaining health behaviors. This process depends on changes in a set of interrelated underlying cognitions such as intention, planning, and self-efficacy [12]. Intention comprises the motivation to perform a behavior [13] and has been identified as the dominant predictor of PA [14, 15]. Intention has been associated with more frequent and higher levels of PA after bariatric surgery [16]. Planning has been recognized as mediator of the relationship between intention and PA in several studies [17-19]. Planning refers to a person's mental

strategies for how to perform a future behavior (action planning) and how to anticipate potential barriers (coping planning) [20]. More planning preoperatively has been associated with higher PA levels among bariatric patients after surgery [21].

Self-efficacy reflects a person's confidence in their ability to perform a certain behavior [22]. Higher self-efficacy has been related to higher levels of self-reported PA [21, 23]. Moreover, individual differences in action control, for example keeping one's goals in mind, monitoring one's progress toward these goals, and exerting effort to reduce any discrepancies between current and intended behavior, play an essential role facilitating maintenance of behavior and to prevent relapses to previous behavior [24-26]. Monitoring exercise daily has been associated with increased PA postoperatively [8]. However, to our knowledge no studies have examined action control in relation to PA after bariatric surgery. Based on the previous the present study aimed at identifying self-regulatory predictors of physical activity after bariatric surgery.

Methods

Participants and study design

Patients eligible for surgery were 18–60 years with a body mass index (BMI) $\geq$ 40 kg/m^2 or $\geq$ 35 kg/m^2 combined with obesity-related comorbidity, and failed previous attempts of sustained weight loss. Questionnaire data were retrieved from the Oslo Bariatric Surgery Study, a prospective cohort study of patients recruited from Oslo University Hospital from 2011 to 2013. Details regarding the recruitment process are previously described [21]. Participants that underwent gastric bypass with questionnaire data (including IPAQ-SF) before and one year after surgery (N = 230) were asked to wear an

ActiGraph GT3X+ accelerometer for seven consecutive days, 18–24 months after surgery. A subsample of 120 (52.2%) patients consented to use the monitor.

Measures

Objective PA

The ActiGraph GT3X+ activity monitor (Actigraph, LLC, Pensacola, FL, USA) was used to assess levels of PA. The participants were instructed to wear the accelerometers on their right hip during all waking hours for seven consecutive days, except during showering and bathing. Participants had to have more than ten hours of valid data per day for at least four days to be included in the analyses. The accelerometer data was used to assess PA levels with regard to mean counts per minute (cpm), sedentary time and minutes of intensity-specific PA, steps taken per day, and percentage of the study population that met the current national PA recommendations. Low, moderate, and vigorous intensity activity were defined as activity in the cpm range of 100–2019, 2020–5998, and 5999 and above, respectively [27, 28]. Adherence to PA recommendations was determined by summing the time spent performing moderate-to-vigorous physical activity in continuous bouts lasting at least 10 minutes (with allowance for 2 interruptions) (bout-related MVPA). If the amount of bout-related MVPA was 150 minutes or more per week, the participant achieved the recommended level of PA.

Self-report PA

The short version of the International Physical Activity Questionnaire (IPAQ-SF) [29] was used to obtain self-reported PA. IPAQ-SF captures time spent in various levels of

activity and mean scores are estimated by weighting type of activity (walking, moderate and vigorous) by energy requirements reported as metabolic equivalent values per week (MET-min/week). Moderate walking is defined as 3.3 METS and moderate intensity is commonly defined as 3–5.9 METS [30]. Thus, to capture all activity of moderate and vigorous intensity a continuous measure of total MET-min/day was used as a measure of self-reported moderate to vigorous PA. Data cleaning and processing was done according to the IPAQ-SF scoring protocol [31]. The recommended level of PA according to the Norwegian National guidelines [3] is 600 MET-min/week based on the IPAQ-SF scoring protocol [31].

Independent variables

Weight was measured on the day of surgery and one year after, using a calibrated Seca 635, III (0–300 kg) platform scale with patients wearing light clothing and no shoes. Postoperative weight loss was used as independent variable to examine whether greater weight loss one year post-surgical would contribute to higher levels of subsequent PA. The independent variables are described in Table 1.

Please insert Table 1 here.

The study protocol was approved by the Regional Ethics Committee for Medical Research (2012/17028) South-Eastern Norway and the Data Protection Officer at Oslo University Hospital. Informed consent was obtained from all participants included in the study.

Statistical analysis

To select variables for the multivariate regression analyses, Pearson correlation coefficients were calculated. Because of high correlations between the psychological variables, a principal component analysis was used to examine if a more parsimonious structure could describe the data. Only variables significantly correlated ($p < .05$) with objective or self-reported PA were included in the hierarchical regression models. Total accumulated MVPA was used as dependent variable in the correlation and regression analyses instead of MVPA in bouts lasting for at least 10 minutes (bout-related MVPA), because 30% of the participants did not accumulate any bout-related MVPA minutes. Independent t-tests and one-way ANOVA were used to compare demographic and psychological variables between groups and between patients in the study sample. Time difference between surgery and IPAQ-SF and monitor data retrieval was not related to any of the study variables and was therefore not included in the analyses.

Results

The final study sample consisted of 112 participants with complete self-report PA data at follow-up and valid accelerometer recordings. The majority of the participants were women (n = 91; 83.1%), most were employed (n = 81; 72.3%), 38 (34.2%) had a college/university degree, and 73 (65.8%) were married/had a partner. Mean height was 170.2 cm (SD = 8.5), and pre- and postoperative weight was 124.9 kg (SD = 19.5) and 89.0 kg (SD = 17.3) respectively. BMI before and post-surgery were 44.8 kg/m^2 (SD = 5.5) and 30.6 kg/m^2 (SD = 5.0) respectively. Percent total weight loss was 28.9% (SD = 7.5).

There were no differences with regard to age, BMI, gender, self-reported levels of PA, or percent total weight loss between the study sample and those who declined to wear the accelerometers. However, there were significant differences in the self-regulatory factors between the two groups. Participants using the monitors scored higher on intention ($p < .01$), self-efficacy ($p < .05$), action planning ($p < .01$), and action control ($p < .05$).

Data describing self-reported and objective measures of PA are listed in Table 2. Regarding objective measures of walking capacity, 19.6% walked less than 5000 steps/day and 13.4% met the commonly recommended level of ≥10.000 steps/day. Adherence to PA guidelines was 80.2% according to subjective measures and 17.9% according to accelerometer data. Differences in demographic, anthropometric, and self-regulation variables depending on whether the participants met the recommended MVPA-level according to objective measures are described in Table 3. Adherence was associated with higher self-efficacy, better action control skills, higher level of education and being single.

Table 4 presents the correlations between the independent variables and objective and subjective MVPA. Intention, action and coping planning, self-efficacy, and action control were positively correlated with objective MVPA. The correlations were small to medium sized, with the strongest correlation being with action control ($r = .34$, $p < .001$). The same variables correlated slightly stronger and positively with self-reported MVPA. A small, negative association between age and self-reported MVPA was found. Weight loss was not associated with PA, but positively correlated with some of the self-regulatory variables.

The self-regulation variables were highly inter-correlated (Table 4). A principal component analysis suggested that these motivational and self-regulatory variables would be best described as a single factor. The first component with an Eigenvalue of 10.2 (all factor loadings above .35) accounted for 57% of the variance and the next component with an Eigenvalue of 1.4 only accounted for additional 8.1% of the variance. A single component labeled "Self-regulation" was therefore extracted, which correlated with objective MVPA ($r = .35$, $p < .001$) and self-reported MVPA ($r = .38$, $p < .001$).

Two-step hierarchical regression analyses (Table 5) tested the unique contribution of the relevant demographic variables and self-regulation on objective and subjective PA. In the first model, being single and higher education level predicted objective MVPA at step 1, accounting for 16.4% of the variance ($p < .001$). Step 2 tested the effect of self-regulation on MVPA and the explained variance increased to 23.5% ($p < .01$). In the second model with subjective MVPA as outcome measure, age was entered in step 1 and accounted for 3% of the variance in self-reported MVPA ($p <. 05$). After entering self-regulation at step 2, the explained variance increased to 15% ($p < .001$). Greater self-regulation emerged as the only significant predictor of self-reported MVPA.

Discussion

The main purpose of this study was to explore levels and predictors of PA after gastric bypass. The accelerometer-based estimates of postoperative PA were considerably lower than subjective estimates, and thus confirm the problem of overestimation when using self-report data. The difference in adherence to recommended PA guidelines according to mode of measure, 17.9% (objective measures) versus 80.2% (self-report) has only been

reported in two previous bariatric surgery studies with similar large discrepancies, but with smaller study samples [35, 36].

Our findings showed that greater weight reduction did not predict higher levels of neither self-reported nor objective PA, contradicting studies describing associations between weight reduction and improved fitness and exercise performance post-surgical [37, 38]. It may be that extensive weight loss and enhanced physical functioning (e.g., reduction in comorbid conditions or weight-related chronic orthopedic pain) results in a subjective feeling of being more capable of performing different activities, which is not always translated into actual behavior [39].

We observed a strong association between intention, self-efficacy, planning, and action control, and higher levels of both objective and self-reported PA. Previous studies have reported associations of intention [16] and planning [21] with self-reported PA, but to our knowledge the current study is the first to examine associations between self-regulatory factors and objective measures of post-surgical MVPA. The high inter-correlation among the psychological variables indicated that participants with higher intention to be physically active also made more plans, were more self-efficacious, and had better action control skills. This pattern also resembles standard advice provided to patients in preparation for surgery, which prompts motivation, confidence, and self-regulation [40]. The statistical overlap between the psychological variables was confirmed in a principal component analysis showing one underlying factor named "self-regulation". In further analyses, self-regulation was identified as an important predictor of both objective and self-reported MVPA. Interventions targeting peoples' abilities to make plans, how to increase self-efficacy, and improve action control skills have proven

to facilitate long-term behavior change in other patient rehabilitation groups [26]. Our findings imply that such interventions may contribute to improved long-term outcomes in bariatric surgery patients.

Self-regulation was the only variable that emerged as predictor of self-reported MVPA, whereas being single was the second variable identified as a positive predictor of objective MVPA when controlling for level of education and self-regulation. To be single or divorced has previously been related to better weight loss outcomes, and it has been suggested that this is because single people are likely to have more time for regular PA [41, 42]. Moreover, partners/spouses influence each other's behavior [43]. The risk of returning to old habits might be higher if previous unhealthy behavior (e.g., sedentary behavior) is upheld by the partner/spouse.

The final unique predictor of objective MVPA was higher education level. This finding coincides with results from a recent report with objective measures of PA in a population-based sample of Norwegian adults [44], and findings from other population-based studies describing subjective PA [45]. Our results indicate that patients with lower education and those in a relationship may have additional need for support to become more physically active post-surgical.

In accordance with evidence from both population-based studies of PA [45] and post-bariatric surgery [8], we found that younger age was associated with higher levels of self-reported MVPA. Further, we found no gender differences in self-reported or objectively measured PA, similar to recent observations both in a bariatric sample [46] and in normal populations using monitor data [27]. King et al. [47], however, found that

men were more active than women, which is also commonly reported in studies with self-reported PA [45].

There are limitations to the study. All participants underwent gastric bypass, and the findings may not be generalizable to other bariatric surgical procedures. Furthermore, an accelerometer located on the trunk may underestimate or miss cycling or upper-body movements [48]. The differences observed for most of the self-regulatory factors between the study cohort and the non-respondents might represent a selection bias. Study strengths were in particular, applying the ActiGraph GT3X+ accelerometer, a widely used and validated activity monitor. Additionally, only participants with valid accelerometer data (≥ four days of recordings) were included in the study sample, with the majority (85.7%) wearing the monitors for six or seven days.

Conclusions

Despite large differences in accelerometer-based and subjective estimates of activity levels, the associations of self-regulatory factors and weight loss with postoperative MVPA did not vary depending on mode of measurement. Self-regulation predicted both objective and self-reported MVPA, suggesting that improving self-regulation capabilities may enhance activity levels after gastric bypass. The findings of poor adherence to recommended level of physical activity indicate that behavioral adjustment constitutes a great challenge after bariatric surgery.

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Authors' contributions

IKL, FFS and IB designed the study. TM, IKL and IB were involved in the data collection. IB, ILK and BHH performed the statistical analyses and IB drafted the manuscript. All authors contributed to the interpretation of the analyses and revisions of the manuscript. All authors have read and approved the final manuscript.

Conflict of Interest

The authors declare that they have no conflict of interests.

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Table 2. Self-reported and objective measures of physical activity per day, post gastric bypass surgery (n = 112)

Variables	Mean	SD
Objective physical activity		
Steps per day	7095.3	2614.3
Sedentary behavior (hours/day)	9.4	1.5
MVPA (min/day)	27.8	20.6
Bout-related MVPA (min/day)*	10.9	13.6
Self-reported physical activity		
Walking (MET-min/day)	184.6	191.9
Moderate intensity (MET-min/day)	83.1	114.7
Vigorous intensity (MET-min/day)	179.4	267.3

Note: MVPA = moderate- to vigorous-intensity physical activity; *All activity < 2020 cpm that occurred in sustained bouts of at least 10 minutes (with allowance for two drops in intensity); MET-min = metabolic equivalent values

Table 3. Differences in study variables depending on adherence to physical activity recommendations (accelerometer data) (n = 112)

	Adherence n = 20	**Non-adherence n = 92**	
Variables	**Mean (SD)**	**Mean (SD)**	**t-value**
Age	46.3 (8.7)	46.9 (9.6)	0.3
BMI (kg/m^2) [a]	30.4 (5.3)	30.7 (5.0)	0.2
Total weight loss % [b]	29.5 (8.4)	28.8 (7.4)	-0.3
Intention	3.4 (0.8)	3.0 (0.8)	-2.2*
Self-efficacy	3.6 (0.6)	3.1 (0.7)	-2.9**
Action planning	3.3 (0.5)	3.1 (0.7)	-1.7
Coping planning	2.9 (0.5)	2.6 (0.7)	-1.6
Action control	3.3 (0.7)	2.9 (0.6)	-2.7**
	n (%)	**n (%)**	χ^2
Gender			2.0
Women	14 (70.0)	77 (83.7)	
Men	6 (30.0)	15 (16.3)	
Education			4.7*
≤ 12 years	9 (45.0)	64 (70.3)	
> 12 years (college/university)	11 (55.0)	27 (29.7)	
Marital status			7.2**
Single	12 (60.0)	26 (28.6)	
Married/Partnered	8 (40.0)	65 (71.4)	

Note; *p < .05; ** p < .01; [a] BMI = body mass index measured one year after surgery; [b] percent total weight loss from day of surgery to one year later; χ^2 = chi square.

Table 4. Correlations between anthropometric, demographic, self-regulatory, and physical activity variables measured after gastric bypass surgery (n = 112)

	1	2	3	4	5	6	7	8	9	10	11	Mean	SD	α
1. Gender	-											1.2	0.4	
2. Age	.19*	-										46.8	9.4	
3. Postoperative BMI (kg/m^2)	.03	. 02	-									30.6	5.0	
4. Intention	-.15	-.17	-.18	-								3.0	0.9	N/A
5. Self-efficacy	-.14	-.06	-.23*	.76***	-							3.2	0.7	.87[a]
6. Action planning	-.14	-.22*	-.13	.76***	.66***	-						3.1	0.7	.94
7. Coping planning	-.06	.01	-.19	.58***	.55***	.71***	-					2.7	0.7	.91
8. Action control	-.02	-.24*	-.14	.76***	.57***	.76***	.64***	-				3.0	0.7	.87
9. % Total weight loss [b]	-.11	-.22*	-.71***	.23*	.32**	.26**	.22*	.24**	-			28.9	7.5	
10. Objective physical activity	.06	-.10	-.11	.31**	.31**	.29**	.25**	.34***	.18	-		10.9	13.6	
11. Self-reported physical activity	.07	-.20*	-.17	.45***	.33***	.31**	.24*	.41***	.15	.24*	-	444.1	429.3	

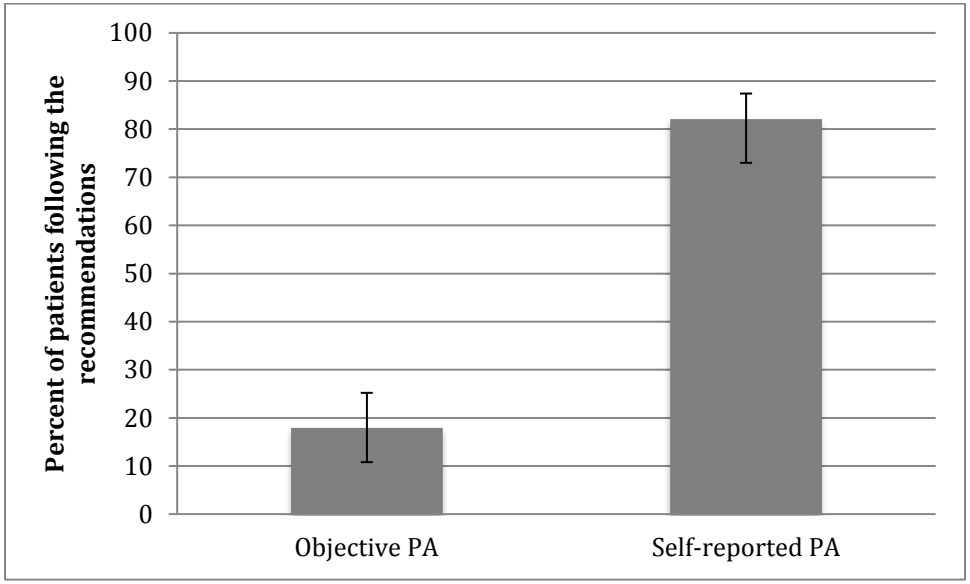
Note: *p<0.05; **p<0.01; ***p<0.001; Postoperative BMI = body mass index (kg/m^2) measured one year after surgery;
α = Cronbach's alpha; N/A = Not applicable; [a] Spearman correlation was applied instead of Cronbach's alpha because self-efficacy was measured by only two items; [b] Percent total weight loss one year after surgery

Table 5**.** Results from hierarchical regression analyses with objective and self-reported physical activity as criterion (n = 112)

	B	β	p-value	95 % CI	R^2_{adj}
Objective physical activity					
Step 1					.16***
Single vs. partner/married [a]	-13.8	-.32	<.001	[-21.35, -6.28]	
Low vs. high education level [b]	7.8	.26	.004	[2.52, 13.06]	
Step 2					.24**
Single vs. partner/married	-13.1	-.30	<.001	[-20.29, -5.86]	
Low vs. high education level	6.2	.21	.018	[1.07, 11.33]	
Self-regulation	5.8	.28	.001	[2.33, 9.32]	
Self-reported physical activity					
Step 1					.03*
Age	-9.3	-.20	.033	[-17.9, -0.78]	
Step 2					.15***
Age	-6.6	-.15	.109	[-14.74, 1.50]	
Self-regulation	152.9	.36	<.001	[76.63, 229.12]	

Note: *p<0.05; **p<0.01; ***p<0.001; [a] Single or partner/married: 0 = single and 1 = partner/married; [b] Education level: 0 = lower education level (≤ 12 years), 1 = higher education level (college/university).

Figure 1. Adherence to physical activity (PA) recommendations in 112 patients after gastric bypass surgery



Note: Objective PA measure = ≥150-min/week of moderate- to vigorous-intensity PA (bout-related MVPA); self-reported PA measure = the short version of the International Physical Activity Questionnaire (IPAQ-SF)