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ORIGINAL CONTRIBUTIONS

Week and Weekend Day Cadence Patterns Long-Term Post-Bariatric Surgery

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Abstract

Obesity can negatively influence walking cadence, reducing the overall intensity of daily activities and increasing the risk of weight gain.

Purpose Objectively describe the walking cadence of individuals' long-term post-bariatric surgery.

Methods Fifty-eight participants, 51.2 ± 8.9 years old, with a BMI of 34.6 ± 10.1 kg/m^2, 10.0 ± 3.1 years post-surgery wore an activPAL accelerometer for 7 consecutive days. Data was analyzed using participants' current BMI, dichotomized by obesity status, < or ≥ 30 kg/m^2.

Results On average, participants walked 5124 ± 2549 steps/day on weekdays and 6097 ± 2786 steps/day on weekend days (p = .003). Participants spent the majority (75%) of their daily steps at a slow-walking average cadence (non-obese: week = 65.3 ± 5.0 steps/min and weekend = 63.8 ± 6.7 steps/min; obese: week = 67.8 ± 8.2 steps/min and weekend = 63.3 ± 6.9 steps/min), with no difference between groups for week or weekend days (p = .153 and .774). The cadence of participants with obesity was significantly lower on weekends compared to weekdays for walking events > 30 s (p = .002) and > 60 s (p = .008) in duration. Weekday cadence of participants without obesity was similar to weekend day cadence across all walking event durations. The majority of walking events occurred below 30 s in duration for all participants.

Conclusions Long-term post-bariatric surgery, movement occurs in short duration bouts at a slow-walking cadence for the majority of movement. Individuals without obesity had similar movement patterns from week to weekend days while participants with obesity significantly lowered their cadence on weekend days.

Keywords Cadence · Obesity · Physical activity · RYGB · Long term

Introduction

In Canada, 26.2% of adults have obesity (BMI ≥ 30 kg/m^2) [1]. Moreover, there has been a ten-fold increase in the prevalence of Class III obesity (BMI ≥ 40 kg/m^2) from the year 1990 (0.4%) [2] to 2015 (4.0%) [3]. Severe obesity is associated with excessive sitting time [4], low activity levels, mobility impairments [5], and several other debilitating metabolic comorbidities [6]. Research has shown that this level of extreme obesity may influence the kinematic parameters of gait,

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resulting in a reduced stride length, widened base of support, and decreased cadence or walking speed, as compared to normal weight individuals [7]. This chronic decrease in cadence represents a reduction in the overall intensity of daily activities, leading to a greater risk of weight gain [8], coronary artery disease [9], and type-2 diabetes [10].

Currently, bariatric surgery is the preferred treatment option for individuals living with severe obesity and other related comorbidities [11]. These surgical procedures are not only known to result in excellent initial weight loss [12] but also a greater self-selected cadence during treadmill walking in a laboratory setting [13] and in a free-living environment [14]. It is hypothesized that these changes in the short-term post-surgery are mostly due to improvements in physical functioning [15] as compared to preoperative levels.

Cadence is an important factor to consider when describing patterns of physical activity. Due to the technical difficulties and financial costs involved in objectively monitoring cadence, most descriptions of physical activity are limited to step counts alone or self-report measures [16]. Evidence from a physical activity intervention in people with overweight and obesity indicates that cadence is an important aspect to monitor as people have accumulated steps at higher cadence despite the lack of any significant changes in total daily steps [17]. High cadence levels (≥ 100 steps/min) throughout the day can indicate periods of moderate to vigorous physical activity (MVPA) [17], which may be just as physiologically important when compared to total daily steps, as this intensity of physical activity is recommended for health-enhancing benefits [18].

As with pre-surgical values [19], in long-term post-surgery, most patients remain inadequately active [15]. Although steps per day and sedentary behavior have been documented [20], to the best of our knowledge there have been no reports describing the walking cadence patterns of this population in the long term (≥ 5 years) after surgery using objective measures. An examination of cadence in this population may offer new insights into the physical activity patterns that emerge long-term post-surgery. Therefore, the aim of this study was to objectively examine the week and weekend day walking cadence patterns in a free-living environment for individuals who have undergone Roux-en-Y gastric bypass (RYGB).

Methods

Individuals who had previously undergone bariatric surgery (5 to 16 years prior to assessment) were recruited for this study through contact by telephone. Former patients were contacted on behalf of their surgeon, in order to complete a long-term post-bariatric surgery follow-up questionnaire and those interested in taking part in this additional study involving monitoring of free-living physical behavior then visited the onsite academic laboratory at McGill University for their assessment. Only ambulatory participants between the ages of 25 and 70 who did not use walking aids were included in this study. The nature, purpose, and risks of the investigation were described to participants and written informed consent was obtained prior to the start of the assessment. This study was approved by the University Medical Ethics Institutional Review Board. Participation in this study was voluntary and participants were not compensated in any way for their contributions. A total of 58 (15 men and 43 women) participants were included in the final data analysis. Participant characteristics are displayed in Table 1.

Height was measured to the nearest centimeter using a Seca 216 wall-mounted stadiometer and weight was assessed to the nearest tenth kilogram using a Seca 635 bariatric platform scale (Seca, Hamburg, Germany). Body composition was assessed using a DXA (GE Healthcare, Chicago, USA) whole body composition scanner using procedures previously described [21]. Lightweight, indoor clothing and no footwear were worn during assessments. Excess weight loss (%) was calculated using ideal weight calculated based on a BMI of 25 kg/m^2 as previously described [22]. Weight regain (%) was calculated as [(current weight − nadir weight) / (pre-surgery weight − nadir weight)] × 100. Data was analyzed using participants' current BMI, dichotomized by obesity status, and < or ≥ 30 kg/m^2.

An activPAL3 activity monitor (PAL Technologies Ltd., Glasgow, UK) was used to record free-living physical behavior. This device was placed in a latex sleeve to prevent sweat from penetrating the connection port and was attached to the anterior aspect of the participant's mid-thigh using a Tegaderm adhesive patch. The activPAL was worn for seven consecutive days to provide free-living physical behavior data. The activPAL was only removed for baths and other aquatic activities where the device would be fully submerged. Participants could change their Tegaderm adhesive patch up to once a day for hygiene purposes. The event-based approach relies on the robust determination of events such as sedentary, standing, and stepping. Each event has three primary parameters: an event label, start time, and duration. The activPAL is a valid measure of posture (sitting or lying, standing, and walking), postural transition [23, 24], step count, and cadence in healthy young [25] and older adults [26].

Event data was extracted using activPAL3 software v17.18.1. A valid day was considered to be at least 10 h of wear-time and a valid wear period was 4–6 days including at least 1 weekend day [27, 28]. Using a Matlab script and activPAL event files, all walking events were extracted including the properties of these events: start time, duration, number of steps, and average cadence. All walking events were analyzed to determine the distribution and relative contributions of these events within different cadence bands to the overall volume of walking. Specifically, cadence across all walking events was analyzed: Number of minutes spent walking within specified cadence bands, proportion of steps taken above a

Table 1 Participant characteristics

	Non-obese (n = 24)	Obese (n = 34)	Total (n = 58)
Pre-surgery age (yrs)	39.72 ± 8.48	42.24 ± 9.73	41.21 ± 9.25
Age (yrs)	50.91 ± 8.64	51.39 ± 9.21	51.19 ± 8.91
Time since surgery (yrs)	11.20 ± 2.90*	9.15 ± 2.97	9.98 ± 3.09
Pre-surgery weight (kg)	128.6 ± 21.95**	157.4 ± 32.85	145.7 ± 32.05
Nadir weight (kg)	64.01 ± 9.87**	91.86 ± 20.41	80.53 ± 21.75
Current weight (kg)	75.45 ± 10.01**	108.8 ± 23.10	95.24 ± 25.01
Weight regain (%)	18.56 ± 10.15*	25.96 ± 15.09	22.95 ± 13.70
Pre-surgery BMI (kg/m^2)	44.26 ± 7.22**	58.75 ± 13.23	52.85 ± 13.22
Nadir BMI (kg/m^2)	22.02 ± 3.21**	34.21 ± 7.87	29.26 ± 8.77
Current BMI (kg/m^2)	26.03 ± 3.55**	40.54 ± 8.81	34.64 ± 10.11
Delta BMI (kg/m^2)	18.23 ± 5.83	18.21 ± 7.36	18.22 ± 6.73
Excess weight loss (%)	96.04 ± 22.90**	54.79 ± 14.49	71.14 ± 27.24
Current body fat (%)	40.98 ± 5.08*	45.43 ± 7.48	43.62 ± 6.92

*$p \leq .05$, different from obese

**$p \leq .001$, different from obese

specified cadence and the cadence below which a set percentage of steps were taken, cadence of purposeful walking (> 30 s, > 60 s and > 120 s). For a more detailed explanation of this data analysis technique, please see M. Granat et al. 2015 [29].

All measures of activity were separated by moment of the week (weekday VS weekend day). Differences in cadence measures by obesity status were explored using ANCOVA adjusting for age, sex, and time since surgery. All statistical tests were considered significant if $p \leq 0.05$ and analyses were performed using version 25 of IBM's SPSS statistical software.

Results

On average, participants walked 5124 ± 2549 steps/day on weekdays and 6097 ± 2786 steps per day on weekend days (p = 0.003). Information concerning cadence in different walking event durations can be found in Fig. 1. Participants spent the majority (75%) of their daily steps at a slow average cadence (non-obese: week = 65.3 ± 5.0 steps/min and weekend = 63.8 ± 6.7 steps/min; obese: week = 67.8 ± 8.2 steps/min and weekend = 63.3 ± 6.9 steps/min), with no mean difference between groups for week or weekend days (p = 0.61 and 0.09 respectively; Table 2). The mean cadence of

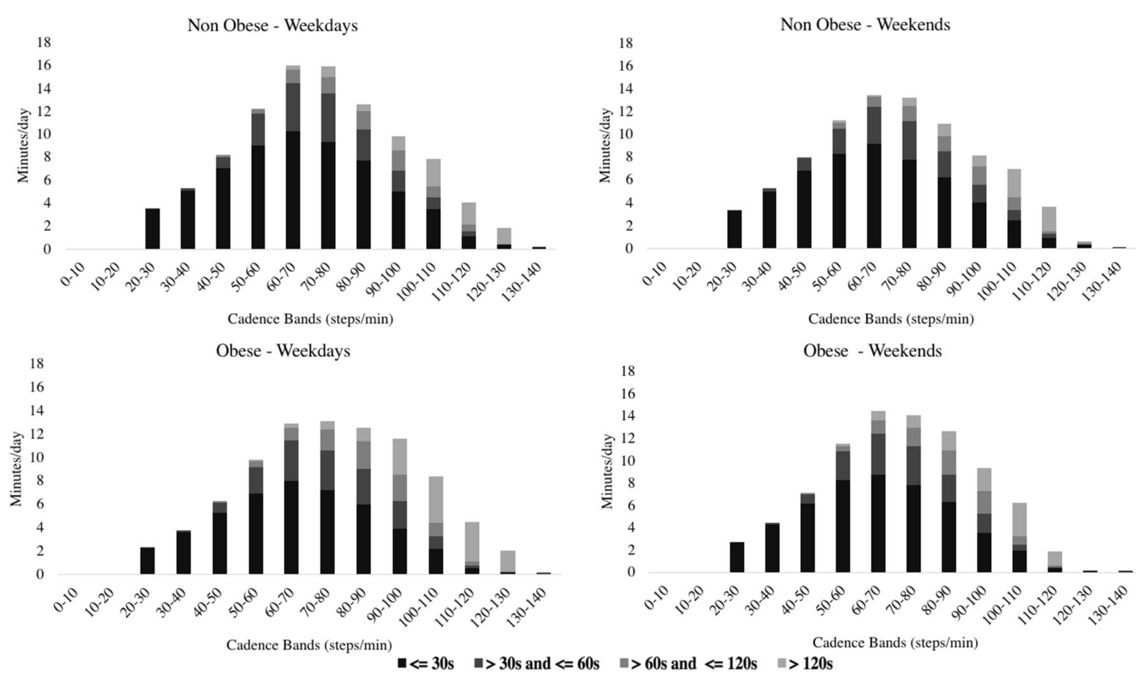

Fig. 1 Mean minutes per day across cadence bands for all walking event durations for participants with and without obesity

Table 2 Cadence of participants with and without obesity on week and weekend days

	Non-obese		Obese		p value (between groups)	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
75% of steps taken above this cadence (steps/min)	65.3 ± 5.0	63.8 ± 6.7	67.8 ± 8.2	63.3 ± 6.9		
p value	.241		.001**		.153	.774
50% of steps taken above this cadence (steps/min)	80.9 ± 7.7	78.6 ± 8.3	82.9 ± 10.8	77.3 ± 9.3		
p value	.117		.001**		.429	.584
25% of steps taken above this cadence (steps/min)	96.3 ± 9.9	93.4 ± 10.1	94.8 ± 11.6	89.2 ± 8.4		
p value	.042*		.002**		.606	.090

*$p \leq .05$, different from weekend

**$p \leq .001$, different from weekend

participants with obesity was significantly lower on weekends compared to weekdays (week: 69.6 ± 4.6 steps/min; weekend: 67.9 ± 4.4 steps/min; $p = 0.002$) for walking events > 30s (week: 78.0 ± 8.2 steps/min; weekend: 74.1 ± 7.5 steps/min; $p = 0.003$) and > 60s (week: 86.4 ± 8.8 steps/min; weekend: 81.2 ± 9.5 steps/min; $p = 0.008$) in duration. Mean weekday cadence of participants without obesity was similar to weekend day cadence across all walking event durations (all $p > 0.05$). There was no significant mean difference between participants with and without obesity for week or weekend day cadence across all walking event durations (all $p > 0.05$).

The percentage of walking events/day in events above duration threshold for participants with obesity was significantly lower on weekends compared to weekdays for walking events > 30 s (week: 8.5 ± 2.3%; weekend: 7.3 ± 2.9%; $p = 0.003$) in duration. The percentage of walking events/day in events above duration threshold for participants without obesity was similar to weekend days across all walking event durations. On weekdays, there were significant mean differences between participants with and without obesity for the percentage of walking events/day in events above duration threshold > 30 s (non-obese: 6.8 ± 2.3%; obese: 8.5 ± 2.3%; $p = 0.041$), > 60 s (non-obese: 1.5 ± 0.85%; obese: 2.5 ± 1.4%; $p = 0.010$), and > 120 s (non-obese: 0.34 ± 0.28%; obese: 0.77 ± 0.79%; $p = 0.034$) in duration. There was no significant mean difference between participants with and without obesity for weekend day walking events (%) across all walking event durations (all $p > .05$).

The percentage of steps/day in events above duration threshold for participants with obesity was significantly lower on weekends compared to weekdays for walking events > 30 s (week: 24.6 ± 2.7%; weekend: 22.7 ± 4.6%; $p = 0.012$) and > 60s (week: 13.7 ± 5.6%; weekend: 11.2 ± 6.7%; $p = 0.03$) in duration. Weekday steps/day (%) of participants without obesity was similar to weekend day values across all walking event durations (all $p > 0.05$). There was no significant mean difference between participants with and without obesity for either weekday or weekend day steps/day (%) across all walking event durations (all $p > 0.05$).

Discussion

On average, long-term post-bariatric surgery, movement occurs in many short duration bouts (less than 30 s in duration) at a relatively slow cadence (i.e., 75% of steps occurred above 60 steps/min). Compared to a nationally representative sample where only 23% of steps were taken above 60 steps/min, bariatric patients seem to be expending a greater percentage of their daily steps at this higher cadence [30]. This nationally representative sample recorded on average 3500 steps per day more than the individuals' post-bariatric surgery equating to more overall movement throughout the day. However, this study used an ActiGraph accelerometer to evaluate cadence, which makes the precise comparison to our results derived from the activPAL difficult. Most previous studies quantifying free-living cadence have used the ActiGraph. The ActiGraph quantifies step accumulation, the number of steps in a fixed period; cadence, the rate of stepping, is not an interchangeable outcome measure [31].

Using the activPAL, with nearly identical methodology to the current study, Granat and colleagues evaluated a population with intermittent claudication (IC), a peripheral arterial disease, and a healthy control group [29]. Regardless of obesity status, and in all measures of cadence, the post-bariatric population was similar to IC and slower/less active than healthy controls. As IC is associated with leg pain caused by inadequate peripheral circulation, people with IC must take regular breaks, limiting their cadence for prolonged walking [32]. Pain has been documented as a major barrier to physical activity in the bariatric population as well [33]. Osteoarthritic joint pain is experienced by the majority of patients presurgery and is mostly relieved post-surgery as weight is lost [34]. Short-duration bouts of movement could be sympathetic to patients experiencing joint pain while walking [34], potentially explaining the similarities noted with IC. This may also be an explanation for why individuals with obesity demonstrate less activity and at slower cadences than non-obese people after bariatric surgery. Osteoarthritic joint pain would be worsened by the presence of more weight being regained in the long-term post-bariatric surgery [34]. In this study, participants with obesity did regain significantly more weight than non-obese participants re-enforcing this theory. Further investigation into movement patterns associated with chronic pain may be useful to develop strategies to help individuals' post-bariatric surgery meet physical activity guidelines.

There were important differences between week and weekend movement patterns by obesity status. Individuals with obesity significantly increased their total steps/day on weekend days compared to weekdays; however, the majority of additional steps came from more walking events of less than 30 s in duration at a significantly lower cadence than their weekday movement. Therefore, these additional step/day were likely not indicative of more intentional exercise. Normal weight individuals maintained similar cadence and steps/day as their weekday movement patterns. A recent study showed that there were significant improvements in physical function with excess weight loss in women 5 years after bariatric surgery. It was shown that patients' gait was a characteristic of their current post-surgical bodyweight rather than their pre-surgical bodyweight, suggesting that years of severe obesity does not permanently alter gait and that gait is primarily influenced by current bodyweight [35]. Our findings suggest that individuals who continue to live with obesity may also continue their pre-surgical gait pattern, associated with a greater step width [36], decreased stride length, decreased percentage of time spent in single support during the gait cycle, and therefore, an overall slower self-selected walking speed [37]. This gait pattern may be considered a cause or consequence of maintaining obesity over time, evidenced by the nadir BMI for this group being 34.21 ± 7.87 kg/m^2, still classified as having obesity even at their lowest weight post-surgery. It is likely that individuals with obesity match the cadence of those without obesity during the week due to environmental factors such as employment, which force them to adhere to the same pace and amount of movement in similar environments [38]. On weekends when the environmental similarities are removed, individuals with obesity can revert to their own self-selected slower cadence.

A strength of our study was using the activPAL accelerometer which is a valid and reliable device for objectively monitoring posture and walking [25]. There has been no detailed description of cadence by week and weekend days in the adult population considering obesity status. Previous descriptions of cadence from nationally representative cohorts [30] have called for these specific types of comparisons.

We acknowledge some limitations in this investigation. The number of male participants was too low for between-sex comparisons. It would be beneficial to evaluate between-sex differences in the bariatric population as differences in cadence in the American population have been identified [30]. Pre-, short-, and mid-term post-surgery measures for our study participants would have been ideal. Unfortunately, as these participants were recruited in the long-term post-surgery, this information was not available. However, given the research describing this population's cadence both pre- and in the short-term post-surgery, we felt that our findings could add to the overall understanding of the bariatric population's movement patterns.

This study demonstrated that, in long-term post-surgery, movement occurs in short bouts of activity at a slow-walking pace. A better understanding of what factors influence the faster movement during weekdays for individuals with obesity may help patients improve levels of activity on weekend days, further helping individuals to achieve national physical activity recommendations.

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Compliance with Ethical Standards

Conflict of Interest Malcolm Granat is a co-director of PAL Technologies Ltd., the company which produces the activPAL the device used for data collection. No other author has a conflict of interest.

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