



University of  
**Salford**  
MANCHESTER

# Week and weekend day cadence patterns long-term post-bariatric surgery

Reid, RER, Granat, MH, Barreira, TV, Haugan, CD, Reid, TGR and Andersen, RE

<http://dx.doi.org/10.1007/s11695-019-03978-2>

<b>Title</b>	Week and weekend day cadence patterns long-term post-bariatric surgery
<b>Authors</b>	Reid, RER, Granat, MH, Barreira, TV, Haugan, CD, Reid, TGR and Andersen, RE
<b>Type</b>	Article
<b>URL</b>	This version is available at: <a href="http://usir.salford.ac.uk/id/eprint/51418/">http://usir.salford.ac.uk/id/eprint/51418/</a>
<b>Published Date</b>	2019

USIR is a digital collection of the research output of the University of Salford. Where copyright permits, full text material held in the repository is made freely available online and can be read, downloaded and copied for non-commercial private study or research purposes. Please check the manuscript for any further copyright restrictions.

For more information, including our policy and submission procedure, please contact the Repository Team at: [usir@salford.ac.uk](mailto:usir@salford.ac.uk).

**Abstract:**

Obesity can negatively influence walking cadence, reducing the overall intensity of daily activities, increasing the risk of weight gain. **Purpose:** Objectively describe the walking cadence of individuals long-term post-bariatric surgery. **Methods:** 58 participants,  $51.2 \pm 8.9$  years old, with a BMI  $34.6 \pm 10.1$  kg/m<sup>2</sup>,  $10.0 \pm 3.1$  years post-surgery wore an activPAL accelerometer for 7-consecutive days. Data was analyzed using participants current BMI, dichotomized by obesity status,  $<$  or  $\geq 30$  kg/m<sup>2</sup>. **Results:** On average, participants walked  $5124 \pm 2549$  steps/day on week days and  $6097 \pm 2786$  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 =  $65.3 \pm 5.0$  steps/min and Weekend =  $63.8 \pm 6.7$  steps/min; Obese: Week =  $67.8 \pm 8.2$  steps/min and Weekend =  $63.3 \pm 6.9$  steps/min), with no difference between groups for week or weekend days ( $p = .153$  and  $.774$ ). Cadence of participants with obesity was significantly lower on weekends compared to week days for walking events  $>30$ s ( $p = .002$ ) and  $>60$ s ( $p = .008$ ) in duration. Week day cadence of participants without obesity was similar to weekend day cadence across all walking event durations. The majority of walking events occurred below 30s 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.

**Introduction:**

In Canada, 26.2% of adults have obesity (BMI  $\geq 30$  kg/m<sup>2</sup>) [1]. Moreover, there has been a ten-fold increase in the prevalence of Class III obesity (BMI  $\geq 40$  kg/m<sup>2</sup>) 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 co-morbidities [6]. Research has shown that this level of extreme obesity may influence the kinematic parameters of gait, 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 co-morbidities [11]. These surgical procedures are not only known to result in excellent initial weight loss [12], but 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 pre-operative 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, indicate that cadence is an important aspect to monitor as people

1  
2  
3  
4 have accumulated steps at higher cadence despite the lack of any significant changes in  
5  
6 total daily steps [17]. High cadence levels ( $\geq 100$  steps/min) throughout the day can  
7  
8 indicate periods of moderate to vigorous physical activity (MVPA) [17], which may be just  
9  
10 as physiologically important when compared to total daily steps, as this intensity of  
11  
12 physical activity is recommended for health enhancing benefits [18].  
13  
14

15  
16 As with pre-surgical values [19], long-term post-surgery, most patients remain  
17  
18 inadequately active [15]. Although steps per day and sedentary behavior have been  
19  
20 documented [20], to the best of our knowledge there have been no reports describing the  
21  
22 walking cadence patterns of this population in the long-term ( $\geq 5$  years) after surgery using  
23  
24 objective measures. An examination of cadence in this population may offer new insights  
25  
26 into the physical activity patterns that emerge long-term post-surgery. Therefore, the aim  
27  
28 of this study was to objectively examine the week and weekend day walking cadence  
29  
30 patterns in a free-living environment for individuals who have undergone roux-en-Y gastric  
31  
32 bypass (RYGB).  
33  
34  
35  
36  
37  
38  
39  
40

#### 41 **Methods:**

42  
43 Individuals who had previously undergone bariatric surgery (5 to 16 years prior to  
44  
45 assessment) were recruited for this study through contact by telephone. Former patients  
46  
47 were contacted on behalf of their surgeon, in order to complete a long-term post-bariatric  
48  
49 surgery follow-up questionnaire and those interested in taking part in this additional study  
50  
51 involving monitoring of free-living physical behavior then visited the onsite academic  
52  
53 laboratory at the University for their assessment. Only ambulatory participants between the  
54  
55 ages of 25 and 70 who did not use walking aids were included in this study. The nature,  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65

purpose, and risks of the investigation were described to participants and written informed consent was obtained prior to the start of 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<sup>2</sup> as previously described [22]. Weight regain (%) was calculated as  $[(\text{Current weight} - \text{Nadir weight}) / (\text{Pre-Surgery Weight} - \text{Nadir weight})] * 100$ . Data was analyzed using participants current BMI, dichotomized by obesity status, < or  $\geq 30$  kg/m<sup>2</sup>.

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 behaviour 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 a 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 hours 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 specified cadence and the cadence below which a set percentage of steps were taken; cadence of purposeful walking (>30seconds (s), >60s and >120s). 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 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  $5124 \pm 2549$  steps/day on weekdays and  $6097 \pm 2786$  steps per day on weekend days ( $p = .003$ ). Detailed information concerning cadence in different walking event durations can be found in table 3 and figure 1. Participants spent the majority (75%) of their daily steps at a slow average cadence (Non-Obese: Week =  $65.3 \pm 5.0$  steps/min and Weekend =  $63.8 \pm 6.7$  steps/min; Obese: Week =  $67.8 \pm 8.2$  steps/min and Weekend =  $63.3 \pm 6.9$  steps/min), with no mean difference between groups for week or weekend days ( $p = .606$  and  $.090$  respectively; Table 2). The mean cadence of participants with obesity was significantly lower on weekends compared to week days (Week:  $69.6 \pm 4.6$  steps/min; Weekend:  $67.9 \pm 4.4$  steps/min;  $p = .002$ ) for walking events  $>30s$  (Week:  $78.0 \pm 8.2$  steps/min; Weekend:  $74.1 \pm 7.5$  steps/min;  $p = .003$ ) and  $>60s$  (Week:  $86.4 \pm 8.8$  steps/min; Weekend:  $81.2 \pm 9.5$  steps/min;  $p = .008$ ) in duration. Mean week day cadence of participants without obesity was similar to weekend day cadence across all walking event durations (all  $p > .05$ ). There was no significant mean difference between participants with and without obesity for week or weekend day cadence across all walking event durations (all  $p > .05$ ).

Detailed information concerning the absolute and relative number of walking events in different walking event durations can be found in table 3. The percentage of walking events/day in events above duration threshold for participants with obesity was significantly lower on weekends compared to week days for walking events  $>30s$  (Week:  $8.5 \pm 2.3\%$ ; Weekend:  $7.3 \pm 2.9\%$ ;  $p = .003$ ) 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 week days, there were significant mean differences between participants with and without obesity for the percentage of

walking events/day in events above duration threshold >30s (Non-Obese:  $6.8 \pm 2.3\%$ ; Obese:  $8.5 \pm 2.3\%$ ;  $p = .041$ ), >60s (Non-Obese:  $1.5 \pm .85\%$ ; Obese:  $2.5 \pm 1.4\%$ ;  $p = .010$ ), and >120s (Non-Obese:  $.34 \pm .28\%$ ; Obese:  $.77 \pm .79\%$ ;  $p = .034$ ) 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  $p > .05$ ).

Detailed information concerning the absolute and relative steps/day in different walking event durations can be found in table 3. The percentage of steps/day in events above duration threshold for participants with obesity was significantly lower on weekends compared to week days for walking events >30s (Week:  $24.6 \pm 2.7\%$ ; Weekend:  $22.7 \pm 4.6\%$ ;  $p = .012$ ), and >60s (Week:  $13.7 \pm 5.6\%$ ; Weekend:  $11.2 \pm 6.7\%$ ;  $p = .032$ ) in duration. Week day steps/day (%) of participants without obesity was similar to weekend day values across all walking event durations (all  $p > .05$ ). There was no significant mean difference between participants with and without obesity for either week day of weekend day steps/day (%) across all walking event durations (all  $p > .05$ ).

## Discussion:

On average, long-term after bariatric surgery, movement occurs in many short duration bouts (less than 30s 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,



1  
2  
3  
4 this study used an ActiGraph accelerometer to evaluate cadence, which makes the precise  
5  
6 comparison to our results derived from the activPAL difficult. Most previous studies  
7  
8 quantifying free-living cadence have used the ActiGraph. The ActiGraph quantifies step  
9  
10 accumulation, the number of steps in a fixed period; cadence, the rate of stepping, is not an  
11  
12 interchangeable outcome measure [31].  
13  
14

15  
16  
17  
18 Using the activPAL, with nearly identical methodology to the current study, Granat  
19  
20 and colleagues evaluated a population with intermittent claudication (IC), a peripheral  
21  
22 arterial disease, and a healthy control group [29]. Regardless of obesity status, and in all  
23  
24 measures of cadence, the post-bariatric population was similar to IC and slower/less active  
25  
26 than healthy controls. As IC is associated with leg pain caused by inadequate peripheral  
27  
28 circulation, people with IC must take regular breaks, limiting their cadence for prolonged  
29  
30 walking [32]. Pain has been documented as a major barrier to physical activity in the  
31  
32 bariatric population as well [33]. Osteoarthritic joint-pain, is experienced by the majority  
33  
34 of patients pre-surgery, and is mostly relieved post-surgery as weight is lost [34]. Short-  
35  
36 duration bouts of movement could be sympathetic to patients experiencing joint pain while  
37  
38 walking [34], potentially explaining the similarities noted with IC. This may also be an  
39  
40 explanation for why individuals with obesity demonstrate less activity and at slower  
41  
42 cadences than non-obese people after bariatric surgery. Osteoarthritic joint pain would be  
43  
44 worsened by the presence of more weight being re-gained in the long-term post-bariatric  
45  
46 surgery [34]. In this study, participants with obesity did re-gain significantly more weight  
47  
48 than non-obese participants, re-enforcing this theory. Further investigation into movement  
49  
50 patterns associated with chronic pain may be useful to develop strategies to help individuals  
51  
52 post-bariatric surgery meet physical activity guidelines.  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65

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 30s in duration at a significantly lower cadence than their week day 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 week day 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 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 overtime, evidenced by the nadir BMI for this group being  $34.21 \pm 7.87 \text{ kg/m}^2$ , 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.

1  
2  
3  
4 A strength of our study was using the activPAL accelerometer which is a valid and  
5 reliable device for objectively monitoring posture and walking [25]. There has been no  
6 detailed description of cadence by week and weekend days in the adult population  
7 considering obesity status. Previous descriptions of cadence from nationally representative  
8 cohorts [30] have called for these specific types of comparisons.  
9  
10  
11  
12  
13  
14

15  
16 We acknowledge some limitations in this investigation. The number of male  
17 participants was too low for between-sex comparisons. It would be beneficial to evaluate  
18 between-sex differences in the bariatric population as differences in cadence in the  
19 American population have been identified [30]. Pre-, short-, and mid-term post-surgery  
20 measures for our study participants would have been ideal. Unfortunately, as these  
21 participants were recruited in the long-term post-surgery, this information was not  
22 available. However, given the research describing this population's cadence both pre- and  
23 in the short-term post-surgery, we felt that our findings could add to the overall  
24 understanding of the bariatric populations movement patterns.  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37

38 This study demonstrated that, long-term post-surgery, movement occurs in short  
39 bouts of activity at a slow-walking pace. A better understanding of what factors influence  
40 the faster movement during week days for individuals with obesity may help patients  
41 improve levels of activity on weekend days, further helping individuals to achieve national  
42 physical activity recommendations.  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52

### 53 **Conflict of Interest:**

54  
55 Author 2 is a co-director of PAL Technologies Ltd, the company which produces the  
56 activPAL the device used for data collection. No other author has a conflict of interest.  
57  
58  
59  
60  
61  
62  
63  
64  
65

**References:**

1. Navaneelan TJ, T. Adjusting the scales: Obesity in the Canadian population after correcting for respondent bias. *Statistics Canada, Catalogue no. 82-624-X \*Health at a Glance*. May 2014:1-10. Available at: <http://publications.gc.ca/site/eng/9.580267/publication.html>.
2. Katzmarzyk PT, Mason, C. Prevalence of class I, II and III obesity in Canada. *CMAJ*. 2006 Jan 17;174(2):156-7. PubMed PMID: 16415457. Pubmed Central PMCID: PMC1329449.
3. Statistics Canada. Distribution of the household population by adult body mass index (BMI) - Health Canada (HC) classification, by sex and age group occasional (percent). March 2019. Available from: <http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=1170005&p2=33>.
4. Bond DS, Unick JL, Jakicic JM, Vithiananthan S, Pohl D, Roye GD, et al. Objective assessment of time spent being sedentary in bariatric surgery candidates. *Obes Surg*. 2011 Jun;21(6):811-4. PubMed PMID: 20393808. Pubmed Central PMCID: PMC2916048.
5. Huang L, Chen P, Zhuang J, Zhang Y, Walt S. Metabolic Cost, Mechanical Work, and Efficiency During Normal Walking in Obese and Normal-Weight Children. *Res Q Exercise Sport*. 2013 Feb 22;84 Suppl 2:S72-9.
6. Eckel RH, Grundy SM, Zimmet PZ. The metabolic syndrome. *Lancet*. 2005 Apr 16-22;365(9468):1415-28.
7. da Silva-Hamu TC, Formiga CK, Gervásio FM, Ribeiro DM, Christofolletti G, de França Barros J. The impact of obesity in the kinematic parameters of gait in young women. *Int J Gen Med*. 2013 Jun;6:507-13.
8. Jakicic JM, Davis KK. Obesity and physical activity. *Psychiatr Clin North Am*. 2011 Dec;34(4):829-40. PubMed PMID: 22098807.
9. Tanasescu M, Leitzmann MF, Rimm E, Willett WC, Stampfer MJ, Hu FB. Exercise Type and Intensity in Relation to Coronary Heart Disease in Men. *JAMA- J Am Med Assoc*. 2002 Oct 15;288:1994-2000.
10. Laaksonen DE, Laaka H-M, Salonen JT, Niskanen LK, Rauramaa R, Laaka TA. Low Levels of Leisure-Time Physical Activity and Cardiorespiratory Fitness Predict Development of the Metabolic Syndrome. *Diabetes care*. 2002 Aug 08;25:1612-8.
11. O'Brien PE. Bariatric surgery: mechanisms, indications and outcomes. *J Gastroenterol Hepatol*. 2010 Aug;25(8):1358-65. PubMed PMID: 20659224.

12. Carey DG, Pliego, G.J. & Raymond, R.L. Body Composition and Metabolic Changes following Bariatric Surgery: Effects on Fat Mass, Lean Mass and Basal Metabolic Rate: Six Months to One- Year Follow-up. *Obes Surg.* 2006;16(12):1602-8.
13. Hortobágyi T, Herring C, Pories WJ, Rider P, Devita P. Massive weight loss-induced mechanical plasticity in obese gait. *J Appl Physiol (Bethesda, Md : 1985).* 2011;111(5):1391-9. PubMed PMID: 21852410.
14. King WC, Hsu JY, Belle SH, Courcoulas AP, Eid GM, Flum DR, et al. Pre- to postoperative changes in physical activity: report from the Longitudinal Assessment of Bariatric Surgery-2 (LABS-2). *Surg Obes Relat Dis.* 2012 Sep 11;8(5):522-32.
15. Josbeno DA, Kalarchian M, Sparto PJ, Otto AD, Jakicic JM. Physical activity and physical function in individuals post-bariatric surgery. *Obes Surg.* 2011 Aug;21(8):1243-9. PubMed PMID: 21153567. Pubmed Central PMCID: PMC4887858.
16. Jacobi D, Ciangura C, Couet C, Oppert JM. Physical activity and weight loss following bariatric surgery. *Obes Rev.* 2011 May;12(5):366-77. PubMed PMID: 20331508.
17. Barreira TV, Harrington DM, Schuna JM, Jr., Tudor-Locke C, Katzmarzyk PT. Pattern changes in step count accumulation and peak cadence due to a physical activity intervention. *J Sci Med Sport.* 2016 Mar;19(3):227-31. PubMed PMID: 25687483.
18. United States Dept of Health and Human Services. 2008 physical activity guidelines for Americans: Government Printing Office. Available at: <https://health.gov/paguidelines/2008/pdf/paguide.pdf>.
19. Galioto R, King WC, Bond DS, Spitznagel MB, Strain G, Devlin M, et al. Physical activity and cognitive function in bariatric surgery candidates. *Int J Neurosci.* 2014 2014/12/01;124(12):912-8.
20. Reid RE, Carver TE, Andersen KM, Court O, Andersen RE. Physical activity and sedentary behavior in bariatric patients long-term post-surgery. *Obes Surg.* 2015 Jun;25(6):1073-7. PubMed PMID: 25702142.
21. Carver TE, Court O, Christou NV, Reid RE, Andersen RE. Precision of the iDXA for visceral adipose tissue measurement in severely obese patients. *Med Sci Sport Exer.* 2014 Jul;46(7):1462-5. PubMed PMID: 24389525.
22. Montero PN, Stefanidis D, Norton HJ, Gersin K, Kuwada T. Reported excess weight loss after bariatric surgery could vary significantly depending on calculation method: a plea for standardization. *Surg Obes Relat Dis.* 2011 Jul 15;7(4):531-4.

- 1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65
23. Grant PM, Ryan CG, Tigbe WW, Granat MH. The validation of a novel activity monitor in the measurement of posture and motion during everyday activities. *Br J Sports Med.* 2006 Dec;40(12):992-7. PubMed PMID: 16980531. Pubmed Central PMCID: PMC2577473.
24. Godfrey A, Culhane KM, Lyons GM. Comparison of the performance of the activPAL Professional physical activity logger to a discrete accelerometer-based activity monitor. *Med Eng Phys.* 2007 Oct;29(8):930-4. PubMed PMID: 17134934.
25. Ryan CG, Grant PM, Tigbe WW, Granat MH. The validity and reliability of a novel activity monitor as a measure of walking. *Br J Sports Med.* 2006 Sep;40(9):779-84. PubMed PMID: 16825270. Pubmed Central PMCID: PMC2564393.
26. Grant MP, Dall PM, Mitchell SL, Granat MH. Activity-Monitor Accuracy in Measuring Step Number and Cadence in Community-Dwelling Older Adults. *J Aging Phys Act.* 2008 Apr;16(2):201-14.
27. Healy GN, Clark BK, Winkler EA, Gardiner PA, Brown WJ, Matthews CE. Measurement of adults' sedentary time in population-based studies. *Am J Prev Med.* 2011 Aug;41(2):216-27. PubMed PMID: 21767730. Pubmed Central PMCID: PMC3179387.
28. Barreira TV, Hamilton MT, Craft LL, Gapstur SM, Siddique J, Zderic TW. Intra-individual and inter-individual variability in daily sitting time and MVPA. *J Sci Med Sport.* 2016 Jun 01;19(6):476-81.
29. Granat M, Clarke C, Holdsworth R, Stansfield B, Dall P. Quantifying the cadence of free-living walking using event-based analysis. *Gait Posture.* 2015 Jun;42(1):85-90. PubMed PMID: 25953505.
30. Tudor-Locke C, Camhi SM, Leonardi C, Johnson WD, Katzmarzyk PT, Earnest CP, et al. Patterns of adult stepping cadence in the 2005–2006 NHANES. *Prev Med.* 2011 Sep 01;53(3):178-81.
31. Dall PM, McCrorie PR, Granat MH, Stansfield BW. Step accumulation per minute epoch is not the same as cadence for free-living adults. *Med Sci Sport and Exer.* 2013 Oct;45(10):1995-2001. PubMed PMID: 23568091.
32. Gardner AW, Montgomery PS, Scott KJ, Blevins SM, Afaq A, Nael R. Association between daily ambulatory activity patterns and exercise performance in patients with intermittent claudication. *J Vasc Surg.* 2008 Nov;48(5):1238-44.
33. Dikareva A, Harvey WJ, Cicchillitti MA, Bartlett SJ, Andersen RE. Exploring Perceptions of Barriers, Facilitators, and Motivators to Physical Activity Among Female Bariatric Patients: Implications for Physical Activity Programming. *Am J Health Promot.* 2016 Sep;30(7):536-44. PubMed PMID: 26559717.

- 1  
2  
3  
4 34. Gill RS, Al-Adra DP, Shi X, Sharma AM, Birch DW, Karmali S. The benefits of  
5 bariatric surgery in obese patients with hip and knee osteoarthritis: a systematic review.  
6 *Obes Rev.* 2011 Aug 25;12(12):1083-9.  
7  
8  
9 35. Froehle AW, Laughlin RT, Teel DD, 2nd, Sherwood RJ, Duren DL. Excess body  
10 weight loss is associated with nonpathological gait patterns in women 4 to 5 years after  
11 bariatric surgery. *Obes Surg.* 2014 Feb;24(2):253-9. PubMed PMID: 24008625. Pubmed  
12 Central PMCID: PMC4013796.  
13  
14  
15 36. Vartiainen P, Bragge T, Lyytinen T, Hakkarainen M, Karjalainen PA, Arokoski  
16 JP. Kinematic and kinetic changes in obese gait in bariatric surgery-induced weight loss.  
17 *J Biomech.* 2012 Jun 26;45(10):1769-74.  
18  
19  
20 37. Vincent HK, Ben-David K, Conrad BP, Lamb KM, Seay AN, Vincent KR. Rapid  
21 changes in gait, musculoskeletal pain, and quality of life after bariatric surgery. *Surg*  
22 *Obes Relat Dis.* 2012 May-Jun;8(3):346-54. PubMed PMID: 22336495.  
23  
24  
25 38. Reid RER, Jirasek K, Carver TE, Reid TGR, Andersen KM, Christou NV, et al.  
26 Effect of Employment Status on Physical Activity and Sedentary Behavior Long-Term  
27 Post-Bariatric Surgery. *Obes Surg.* 2018 Mar;28(3):869-73. PubMed PMID: 29307108.  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65