Published in final edited form as:
Surg Obes Relat Dis. 2008 ; 4(6): 721–728. doi:10.1016/j.soard.2008.08.022.

Physical Activity Levels of Patients Undergoing Bariatric Surgery in the Longitudinal Assessment of Bariatric Surgery (LABS) Study

W.C. King[1], **S. H. Belle**[1], **G.M. Eid**[2], **G.F. Dakin**[3], **W.B. Inabnet**[4], **J.E. Mitchell**[5], **E.J. Patterson**[6], **A.P. Courcoulas**[2], **D.R. Flum**[7], **W.H. Chapman**[8], and **B. M. Wolfe**[9]

1 *University of Pittsburgh, Graduate School of Public Health, Pittsburgh, PA, USA*

2 *University of Pittsburgh Medical Center, Pittsburgh, PA, USA*

3 *Weill Cornell Medical College, New York, NY, USA*

4 *Columbia University, New York, NY, USA*

5 *University of North Dakota/Neuropsychiatric Research Institute, Fargo, ND, USA*

6 *Legacy Good Samaritan Hospital, Portland, OR, USA*

7 *University of Washington, Seattle, WA, USA*

8 *East Carolina University, Brody School of Medicine, Greenville, NC, USA*

9 *Oregon Health & Science University, Portland, OR, USA*

Abstract

Background—Bariatric surgery candidates' physical activity (PA) level may contribute to the variability of weight loss and body composition changes following bariatric surgery. However, there

---

Corresponding Author: Wendy King, PhD, Research Assistant Professor, Department of Epidemiology, University of Pittsburgh, Graduate School of Public Health, 130 DeSoto Street, Office A533, Pittsburgh, PA 15261, 412-624-1612 (phone), 412-624-7397 (fax), kingw@edc.pitt.edu.

LABS personnel contributing to the study include: **Columbia University Medical Center, New York, NY:** Paul D. Berk, MD, Marc Bessler, MD, Amna Daud, MD, MPH, Dan Davis, DO, W. Barry Inabnet, MD, Munira Kassam, Beth Schrope, MD, PhD **Cornell University Medical Center, New York, NY:** Greg Dakin, MD, Faith Ebel, Michel Gagner, MD, Jane Hsieh, Alfons Pomp, MD, Gladys Strain, PhD **East Carolina Medical Center, Greenville, NC:** Rita Bowden, RN, William Chapman, MD, FACS, Lynis Dohm, PhD, John Pender MD, Walter Pories, MD, FACS **Neuropsychiatric Research Institute, Fargo, ND:** Michael Howell, MD, Luis Garcia, MD, Michelle Kuznia, BA, Kathy Lancaster, BA, James E. Mitchell, MD, Tim Monson, MD, Jamie Roth, BA **Oregon Health & Science University:** Clifford Deveney, MD, Stefanie Green, Robyn Lee, Jonathan Purnell, MD, Robert O'Rourke, MD, Chad Sorenson, Bruce M. Wolfe, MD, Zachary Walker **Legacy Good Samaritan Hospital, Portland, OR:** Valerie Halpin, MD, Jay Jan, MD, Crystal Jones, Emma Patterson, MD, Milena Petrovic, Cameron Rogers **Sacramento Bariatric Medical Associates, Sacramento, CA:** Iselin Austrheim-Smith, CCRP, Laura Machado, MD **University of Pittsburgh Medical Center, Pittsburgh, PA:** Anita P. Courcoulas, MD, MPH, FACS, George Eid, MD, William Gourash, MSN, CRNP, Lewis H. Kuller, MD, DrPH, Carol A. McCloskey MD, Ramesh Ramanathan MD **University of Washington, Seattle, WA:** David E. Cummings, MD, E. Patchen Dellinger, MD, David R. Flum, MD, MPH, Kris Kowdley, MD, Juanita Law, Kelly Lucas, BA, Brant Oelschlager, MD, Andrew Wright, MD **Virginia Mason Medical Center, Seattle, WA:** Lily Chang, MD, Stephen Geary, RN, Jeffrey Hunter, MD, Ravi Moonka, MD, Olivia A. Seibenick, CCRC, Richard Thirlby, MD **Data Coordinating Center, Graduate School of Public Health at the University of Pittsburgh, Pittsburgh, PA:** Steven H. Belle, PhD, MScHyg, Michelle Caporali, BS, Wendy C. King, PhD, Kevin Kip, PhD, Kira Leishear, BS, Laurie Koozer, BA, Debbie Martin, BA, Rocco Mercurio, MBA, Faith Selzer, PhD, Abdus Wahed, PhD **National Institute of Diabetes and Digestive and Kidney Diseases:** Mary Evans, Ph.D, Mary Horlick, MD, Carolyn W. Miles, PhD, Myrlene A. Staten, MD, Susan Z. Yanovski, MD **National Cancer Institute:** David E. Kleiner, MD, PhD

NIH-PA Author Manuscript
NIH-PA Author Manuscript

is little research describing the PA of patients undergoing bariatric surgery to inform PA recommendations in preparation for, and following, surgery.

Objectives—Describe PA assessment in the LABS-2 study and report pre-surgery PA level. Examine relationships between objectively determined PA level and 1) BMI and 2) self-reported purposeful exercise.

Setting—Six sites in the U.S.

Methods—Participants wore an accelerometer and completed a PA diary. Standardized measures of height and weight were obtained.

Results—Of 757 participants, 20% were sedentary (<5000 steps/day), 34% low active (5000-7499 steps/day), 27% somewhat active (7500-9999 steps/day), 14% active (10000-12499 steps/day), and 6% were highly active (≥12500 steps/day). BMI was inversely related to mean steps/day and mean steps/minute during the most active 30 minutes each day. The most commonly reported activities were walking, 44%; gardening, 11%; playing with children, 10%; and stretching, 7%. Self-report of minutes of exercise accounted for 2% of the variance in objectively determined steps.

Conclusion—Patients present for bariatric surgery with a wide range of PA levels, with almost half categorized as somewhat active or active. BMI is inversely related to total amount and intensity of PA. Few patients report a regular pre-operative exercise regimen suggesting most PA is accumulated from activities of daily living. Patient report of daily minutes of walking or exercise may not be a reliable indication of their PA level.

Keywords

obesity; morbid bariatric surgery; physical activity; accelerometer; objective exercise

Introduction

Clinical guidelines for treating overweight and obese people include increasing physical activity (PA) as part of a comprehensive weight loss program and long-term weight management [1]. To lose weight, 60 minutes of moderate-to-vigorous intensity PA on most days in conjunction with a nutritious eating plan that results in a negative energy balance is recommended [2]. However, behavioral interventions do not have proven efficacy for substantial weight loss in adults with severe obesity (body mass index [BMI] ≥40 kg/m^2) [3].

Although PA alone has a poor record of success for treating severe obesity, within the context of bariatric surgery, different levels of PA might contribute to the wide range of weight loss that follows operative intervention [4,5]. In addition, studies of non-surgical weight loss have shown that PA during weight loss improves body composition by maintaining lean body mass of muscle and bone, and maximizing fat loss [6], and that regular PA is important for successful long-term weight control [1,6]. Thus, PA may help to prevent post surgical weight regain after weight nadir. Finally, numerous studies have linked increased PA participation with improvements in physical function, fine-tuning metabolic homeostasis, achieving endocrine and immunologic health, and enhancing mental heath, suggesting PA might play an important role in co-morbidity resolution following bariatric surgery independent of weight loss. Given the potential importance of PA on outcomes of bariatric surgery, research is needed to determine the PA level of surgical candidates, to inform PA recommendations in preparation for, and following, surgery, as well as to investigate relationships between PA and outcomes of bariatric surgery.

Surveys are most frequently used to assess PA because they measure habitual PA and compared to other PA assessment methods, surveys are low in cost, easy to administer, and have low participant burden [7,8]. However, surveys are subject to social desirability bias (i.e., systematic over-reporting of “good” practices) and recall bias (i.e., differentiation in ability to accurately recall type, intensity, duration, and frequency of activities) [7-9], which is especially problematic when studying people whose PA is primarily through activities of daily living (e.g., housework) since it is more difficult to accurately describe and recall these activities compared to purposeful exercise [9].

Due to the challenges of accurately assessing PA by survey, objective measurement devices such as pedometers, which measure steps, and accelerometers, which measure movement intensity as counts or steps per time interval, are the best options for assessing habitual PA in large studies [10]. Both types of devices can measure total PA level. Accelerometers can also be used to describe activity patterns and determine PA intensity because the data are time stamped. Newer devices are small, can store data over multiple days, and are increasingly reliable and affordable [10].

The Longitudinal Assessment of Bariatric Surgery (LABS)-2 [11], an observational study following bariatric surgery patients at six clinical sites throughout the United States, is the first study to assess bariatric surgical candidates' PA level using accelerometry.

Accelerometer selection and study protocols were developed in accordance with the best practices and research recommendations for accelerometer use [10,12]. The purpose of this paper is to describe PA assessment in the LABS-2 study and report objectively determined pre-surgical PA levels and self-report of purposeful exercise. A secondary objective is to examine the relationships between objectively determined PA and both BMI and self-reported purposeful exercise.

Methods

Subjects

LABS is a longitudinal observational study designed to assess the risks and benefits of bariatric surgery [11]. Patients at least 18 years old seeking their first bariatric surgery by participating surgeons at six clinical sites (see appendix) are approached for participation. Details of the LABS-2 evaluations have been previously reported [11]. The LABS-2 protocol and consent form were approved by the Institutional Review Board at each institution. Recruitment began in March, 2006 and is ongoing. Participants who proceeded to surgery by March 14, 2008 (n=1343) were eligible to be included in these initial analyses.

Patient Characteristics

Participants self-reported birthdate, race, ethnicity, marital, occupational status, income, education, ability to walk unassisted and assisted, and use of walking aids. Standardized protocols were used to measure weight and height within 30 days of surgery.

PA Assessment

The StepWatch™ 3 Activity Monitor (SAM, OrthoCare Innovations, Washington, D.C.) is a microprocessor-controlled biaxial accelerometer, accurate in lean and obese individuals at “slow” (i.e., 1 mph) and “purposeful walking” (2 and 3 mph) paces and with a variety of gait styles with accuracy typically exceeding 98% [13]. Fastened above the ankle using Velcro closures, the SAM combines acceleration, position, and timing information to count steps taken. Steps are recorded in 1-minute intervals synchronized to a 24-hour clock. Thus it can be used to determine daily steps like a pedometer, and to characterize PA intensity.

Study staff at LABS clinical centers was trained before PA assessment began. During the pre-surgical research visit, the SAM was programmed with sensitivity settings appropriate to the participant's height, cadence, and gait speed using accompanying software [13] and validated at different walking speeds. Participants were asked to wear the SAM at least during waking hours for the seven consecutive days following their clinic visit, with an option to wear the monitor continuously. Participants were also given a PA diary to record for how long the monitor was removed during waking hours. If participants reported that they did not wear, or removed the SAM for more than five hours in a day, the diary prompted them to wear the SAM an additional day. The diary also assessed activities done specifically for exercise and the duration of each activity (diary available at http://www.edc.gsph.pitt.edu/labs/Public/LABS-1DescriptionPaper/StepwatchActivityDiary.pdf). Participants returned diaries and monitors via mail to study staff who visually reviewed the data to determine protocol compliance. Participants with inadequate monitor wear-time were asked to repeat the PA assessment if time allowed.

Of the 1343 LABS-2 participants who proceeded to surgery by March 14, 2008, 991 (74%) participated in the PA assessment. Patients were excluded from PA assessment if they had a medical condition that could be exacerbated by wearing the monitor (e.g., edema) (n=2), a health related reason other than obesity that limited walking (e.g., multiple sclerosis) (n=3), a temporary injury that affected walking (e.g., sprained ankle) (n=3), or if they exclusively used a wheel chair (n=6). Participants were also excluded from PA assessment if their baseline clinical visit was within 3 days of surgery (n=156), they did not attend a pre-surgical clinic visit (n=1), no monitors were available for distribution (n=144), or they refused to wear the SAM (n=34). The reason an additional 3 participants were excluded has not yet been resolved.

PA Data Processing

Accelerometer data processing protocols determine which participants and assessment days are included in analysis, which in turn affects estimates of PA [14,15]. Details of the LABS-2 SAM data processing protocol are presented elsewhere [16]. Briefly, raw SAM data (steps per minute) from the manufacturer software were exported to a database and algorithms developed in SAS software, version 9.1 (SAS Institute Inc, Cary, NC) were used to determine monitor non-wear and wear-time. Non-wear was defined by an interval of at least 120 consecutive minutes with no more than 1 step/minute. A valid day required 10 or more hours of monitor wear-time. Participants were excluded from analysis if they failed to provide at least three days with at least 10 hours/day of wear-time. Including those with at least 3 days of valid wear provided estimates of physical activity comparable to those obtained from those with at least 7 days of valid wear (data not shown), but increased the sample size substantially. Of the 991 participating in PA assessment, 141 (14%) had insufficient wear-time, 38 (4%) failed to return the monitor, the monitor data for 14 (1%) could not be downloaded due to technical problems, the data file of 13 was lost, and the data files of 25 (3%) was received after data analyses was completed, leaving 757 (76%) for analyses. To adjust for differing lengths of wear-time on valid days and the number of days of PA assessment, mean wear-time per day, and number of days of PA assessment were considered in multivariable analyses.

PA Measures

Raw SAM data were used to calculate measures of total PA and peak PA intensity. Mean steps per day was calculated by dividing the total number of steps accumulated on all valid days by the number of valid days. PA level categories based on mean steps/day cut points (sedentary: less than 5000 steps, low active: 5000-7499 steps, somewhat active: 7500-9999 steps, active: 10000-12499 steps, and highly active: 12500+ steps) developed for healthy adults [17] were also applied. A peak PA index was calculated, in which the mean steps per minute during the most active (non-continuous) 30 minutes of the day, was averaged across all valid days. In addition, self-reported mean minutes/day of 1) exercising and 2) walking for exercise were determined.

Statistical analyses

Potential selection bias was examined by comparing socio-demographic and anthropometric characteristics of LABS-2 participants in the analysis sample to those excluded due to no, or inadequate, PA data using chi square tests for categorical variables and the t-test for continuous variables. BMI was log transformed to produce a normal distribution for the t-test.

PA measures were tabulated by BMI groups (<40 kg/m^2, 40-<50 kg/m^2, 50-<60 kg/m^2 and ≥60 kg/m^2) for descriptive purposes. The Mantel-Hansel test for trend was used to test for an association between BMI groups and PA categories. Multivariable regression was used to test for an association between BMI, as a continuous variable, and mean steps/day and peak PA intensity (mean steps/min during the most active 30 minutes of the day), controlling for monitor wear time and number of days of PA assessment.

Data from the PA diary were summarized. Pearson correlation was used to test for an association between mean steps/day and self-report of mean minutes/day of 1) exercising and 2) walking for exercise. All analyses were conducted with SAS, version 9.1 (SAS Institute Inc, Cary, NC). Significance was defined as p<.05.

Results

Characteristics of the study sample are presented in Table 1 by PA assessment status. Comparing participants included in PA analysis to participants with insufficient PA data and participants excluded from PA assessment, there were no significant differences in sex, age, ethnicity, race, or education (p>.05). This may be due to the large number of exclusions due to insufficient time to obtain adequate wear (n=156) or unavailability of monitors (n=145) both of which are a result of scheduling, not patient characteristics. On the other hand, included participants were more likely to be employed full-time for pay (61.7% vs. 55.6%, p=.03), have a higher annual household income (e.g., 83.8% vs. 76.6% at least $25,000, p=.03), and a lower BMI (mean 47.4 kg/m^2 vs. 48.4 kg/m^2, p=.03). These differences may have been due to the PA assessment protocol which excluded participants if they exclusively used a wheel chair or had a health condition other than obesity that limited walking. Of note, participants included in the PA analyses were just as likely to report using a cane (9.8% vs. 10.9%, p=.52) or a walker (3.2% vs. 4.4%, p=.25) as participants not in the PA analysis.

Participants (N=757) averaged (± sd) 7569±3159 steps/day and 72.4±15.4 steps/min for their most active 30 minutes of the day (Table 2). Whereas 20% of participants were sedentary, nearly the same percentage was active or highly active. The percentage of sedentary patients increased with higher BMI while the percentages in the most active groups (≥10,000 steps/day) decreased with increasing BMI (p<0.0001).

BMI was inversely associated with mean steps/day after controlling for monitor wear-time such that a 1 kg/m^2 increase in BMI was associated with 148.3 fewer steps/day (p<.0001). BMI was also inversely related to peak PA intensity after controlling for wear-time such that a 1 kg/m^2 increase in BMI was associated with 0.70 fewer steps/minute during the most active 30 minutes of the day (p<.0001). Including the number of days of PA assessment in the multivariable model did not alter the relationship between BMI and PA measures.

Six hundred and forty of 757 participants (85%) with valid SAM data returned a diary with at least 3 days completed. Of these, 39% reported not doing any activities specifically for exercise and another 20% averaged less than 10 minutes of exercise per day, while 18% averaged 30 or more minutes per day. The most commonly reported activity was walking (42%), accounting for just over half of the minutes of reported exercise. Other popular activities were playing with children, 10%; gardening, 9%; stretching, 6%; and swimming, water jogging, weight lifting, biking, and dancing, 3% each. Among those who reported any exercise and indicated duration (n=368), reported minutes of exercise only accounted for 2% of the variance in objectively determined steps (r=.15, p<.01). Similarly, among those who reported any walking and indicated duration (n=256), reported minutes of walking accounted for 5% of the variance in steps (r=.23, p<.001).

Discussion

To date this is the largest study of PA in bariatric candidates, with participants coming from six sites throughout the country. In addition, this is the first study in this field to use objective assessment of PA. While many commercially available pedometers and accelerometers have been validated in normal and overweight adults, almost all monitors are inaccurate at slow walking speeds [18-23] and for unusual gaits [24], both of which are common in the severely obese [25]. However, this study used the SAM, with proven accuracy and precision [13].

While few studies have examined PA in the bariatric surgical population, there is a general belief that most bariatric patients are deconditioned and inactive [26]. Thus, it is not surprising that when comparing the PA level of bariatric surgical candidates to “healthy” adults from other studies that have used the SAM, bariatric candidates appear less active as a group. For instance, a study with 12 healthy adults (mean age 34 yrs; mean BMI 26 kg/m^2) reported a mean (SD) of 12648 (2444) steps/day [27]. Likewise, a study including 30 healthy younger adults (mean age 37 yrs; mean BMI 26 kg/m^2) and 28 healthy older adults (mean age 84 yrs; mean BMI 24 kg/m^2) reported higher PA levels for both groups (mean (SD) of 11075 (2908) steps/day and 9982 (1564) steps/day, respectively) [28], as did a study of 129 older adults (mean age 64 yrs; mean BMI 30 kg/m^2; mean (SD) of 8460 (3416) steps/day) [29]. While on average bariatric surgical candidates appear to be less active, the current effort found 27% classified as somewhat active, 14% as active and 6% as highly active using steps per day cut points established for healthy adults. These PA levels (≥somewhat active) are high enough to attain measurable health benefits [30-32]. However, a recent study indicates that adults need to walk at least 10,000-12,000 steps per day, depending on age and sex, to maintain a healthy weight [33]. Thus, it will likely be important for bariatric patients to increase their PA post surgery to maintain their initial weight loss.

In addition to total PA level, the intensity of peak PA was examined. The peak PA index (mean steps per min for the most active 30 minutes of the day) of bariatric surgery candidates appears higher on average (mean (SD) of 72.4 (15.4) steps/min) than the peak PA index reported in the study of 129 older adults (61.6 (14.8) steps/min)[29]. However, it was substantially lower than the 105 (9.4) steps/min reported in the study of 12 healthy adults [27]. While more comparative data are needed, this analysis suggests that the intensity of peak PA of surgical candidates may be lower than that of healthy young to middle age adults but not as low as that of healthy older adults.

The inverse relationship we found between BMI and mean steps/day is similar to several studies that have examined this relationship in samples with weight ranges of normal weight to obese [33-38]. However, this was the first study to show this relationship continues within class 3 obesity. The current effort also showed that BMI is inversely related to intensity of peak PA.

Because accelerometers do not record specific activities or their frequency, a PA diary was used to capture data on activities participants do specifically for exercise. Few patients reported a regular pre-operative exercise regimen suggesting that most of their PA is from activities of daily living. Similar to the US adult population [39], walking was by far the most commonly reported exercise. The only other activities reported by more than 3% of surgical candidates were playing with children, gardening, and stretching.

Given that this sample accumulated most of their PA through activities of daily living and that the PA diary only assessed activities done specifically for exercise, there was not likely to be a strong correlation between the diary and accelerometer data. However, because of its potential value in clinical practice, we examined whether self-reported exercise might be indicative of overall PA level in this population. While self-report of minutes of walking and minutes of exercise were both significantly related to objectively determined step counts in those that reported any walking or exercise, they only accounted for 2-5% of the variance in objectively determined PA level. Thus, patient report of exercise may not be a reliable indication of PA level among bariatric surgery candidates.

It is important to recognize some limitations of this study. First, the use of a single ankle-mounted accelerometer, which only measures leg movement, misses some PA that involves upper body movement or the additional energy cost of load-carrying. Second, while the PA diary used in this study underwent pilot testing in bariatric candidates before study initiation to ensure that relevant activities were included, its psychometric properties have not been established. Third, while the peak PA index used in this analysis gave an indication of PA intensity, it is not a widely used measure and does not translate into minutes of moderate or vigorous intensity PA. Thus it can not be used to determine compliance to national PA guidelines. Future work is needed to determine appropriate cut points for moderate and vigorous intensity PA in this population. Finally, due to exclusion criteria, PA results are not generalizable to bariatric surgery candidates who exclusively use a wheel chair or have a medical condition other than obesity that limits walking. However, participants included in the PA analyses were just as likely to report using a cane or a walker as those excluded from PA analyses.

Conclusion

Adults present for bariatric surgery with a wide range of PA levels, with almost half somewhat active or active. BMI is inversely related to both the total amount and intensity of PA. Few patients report a regular pre-operative exercise regimen suggesting most PA comes from activities of daily living. Patient report of daily minutes of walking or exercising may not be a reliable indication of their total PA level. Given, the variation in PA level of bariatric candidates, their capabilities for either initiating a PA program or increasing their PA level prior to surgery vary dramatically. A pre-surgical PA assessment can be used by the bariatric surgical team to determine an appropriate PA goal in preparation for and following surgery. Future research is needed to determine whether PA assessment prior to surgery may assist the clinician with risk stratification, and when, how much, and what kinds of PA positively impact outcomes of bariatric surgery. LABS-2, which includes PA assessment annually following surgery, will address these questions in future analyses.

Acknowledgements

LABS Study Acknowledgments: This clinical study was a cooperative agreement funded by the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). Grant numbers: DCC -U01 DK066557; Columbia-Presbyterian - U01-DK66667; University of Washington - U01-DK66568 (in collaboration with GCRC, Grant M01RR-00037); Neuropsychiatric Research Institute - U01-DK66471; East Carolina University – U01-DK66526; University of Pittsburgh Medical Center – U01-DK66585; Oregon Health & Science University – U01-DK66555.

References

1. National Heart Lung and Blood Institute NHLBI. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults-executive summary. NIH. 1998. http://www.nhlbi.nih.gov/guidelines/obesity/sum_clin.htm
2. National Institutes of Diabetes and Digestive and Kidney Disease. Physical activity and health. NIH. 2006. http://win.niddk.nih.gov/publications/physical.htm#Physical_Activity_and_Weight_Control
3. Wadden TA, Sternberg JA, Letizia KA, Stunkard AJ, Foster GD. Treatment of obesity by very low calorie diet, behavior therapy, and their combination: a five-year perspective. Int J Obes 1989;13:39–46. [PubMed: 2613427]
4. Evans RK, Bond DS, Wolfe LG, et al. Participation in 150 min/wk of moderate or higher intensity physical activity yields greater weight loss after gastric bypass surgery. Surg Obes Relat Dis 2007;3:526–30. [PubMed: 17903772]
5. Welch G, Wesolowski C, Piepul B, Kuhn J, Romanelli J, Garb J. Physical activity predicts weight loss following gastric bypass surgery: findings from a support group survey. Obes Surg. 2008Epub ahead of print
6. Rippe JM, Hess S. The role of physical activity in the prevention and management of obesity. J Am Diet Assoc 1998;10(Suppl 2):S31–S38. [PubMed: 9787734]
7. Dale, D.; Welk, GJ.; Matthews, CE. Physical activity assessments in health related research. In: Welk, GJ., editor. Selecting appropriate physical activity assessment techniques. Champaign, IL: Human Kinetics Publishers; 2002. p. 19-34.
8. Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. Res Q Exerc Sport 2000;71(2 Suppl):S1–S14. [PubMed: 10925819]
9. Duncan GE, Sydeman SJ, Perri MG, Limacher MC, Martin AD. Can sedentary adults accurately recall the intensity of their physical activity? Prev Med 2001;33:18–26. [PubMed: 11482992]
10. Ward DS, Evenson KR, Vaughn A, Rodgers AB, Troiano RP. Accelerometer use in physical activity: best practices and research recommendations. Med Sci Sports Exerc 2005;37(11 Suppl):S582–S588. [PubMed: 16294121]
11. Belle SH, Berk PD, Courcoulas AP, et al. Safety and efficacy of bariatric surgery: Longitudinal Assessment of Bariatric Surgery. Surg Obes Relat Dis 2007;3:116–26. [PubMed: 17386392]
12. Trost SG, McIver KL, Pate RR. Conducting accelerometer-based activity measurements in field-based research. Med Sci Sports Exerc 2005;37(11 Suppl):S531–S543. [PubMed: 16294116]
13. Boone DA, Coleman KL. Use of a step activity monitor in determining outcomes. J Prosthet Orthot 2006;18(1S):86–92.
14. Corder K, Brage S, Ekelund U. Accelerometers and pedometers: methodology and clinical application. Curr Opin Clin Nutr Metab Care 2007;10:597–6039. [PubMed: 17693743]
15. Masse LC, Fuemmeler BF, Anderson B, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. Med Sci Sports Exerc 2005;37(11 Suppl):S544–S554. [PubMed: 16294117]
16. King, WC.; Li, J.; Leishear, K.; Mitchell, JE.; Belle, SH. Accelerometer data reduction influences estimates of physical activity. The Obesity Society Annual Conference; 2008.
17. Tudor-Locke C, Bassett DR Jr. How many steps/day are enough? Preliminary pedometer indices for public health. Sports Med 2004;34(1):1–8. [PubMed: 14715035]
18. Crouter SE, Schneider PL, Karabulut M, Bassett DR. Validity of 10 electronic pedometers for measuring steps, distance, and energy cost. Med Sci Sports Exerc 2003;35(8):1455–1460. [PubMed: 12900704]
19. Cyarto EV, Myers AM, Tudor-Locke C. Pedometer accuracy in nursing home and community-dwelling older adults. Med Sci Sports Exerc 2004;36(2):205–209. [PubMed: 14767241]
20. Esliger DW, Probert A, Gorber SC, Bryan S, Laviolette M, Tremblay MS. Validity of the Actical accelerometer step-count function. Med Sci Sports Exerc 2007;39(7):1200–1204. [PubMed: 17596790]
21. Foster RC, Lanningham-Foster LM, Manohar C, et al. Precision and accuracy of an ankle-worn accelerometer-based pedometer in step counting and energy expenditure. Prev Med 2005;41:778–783. [PubMed: 16125760]

22. Melanson EL, Knoll JR, Bell ML, et al. Commercially-available pedometers: considerations for accurate step counting. Prev Med 2004;39:361–8. [PubMed: 15226047]
23. Swartz AM, Bassett DR Jr, Moore JB, Thompson DL, Strath SJ. Effects of body mass index on the accuracy of an electronic pedometer. Int J Sports Med 2003;24:588–92. [PubMed: 14598195]
24. Haeuber E. Accelerometer monitoring of home- and community-based ambulatory activity after stroke. Arch Phys Med Rehabil 2004;85:1997–2001. [PubMed: 15605339]
25. Spyropoulas P, Pisciotta JC, Pavlou KN, Cairns MA, Simon SR. Biomechanical gait analysis in obese men. Arch Phys Med Rehabil 1991;72:1065–70. [PubMed: 1741658]
26. Garber CE. The role of the clinical exercise physiologist in the interdisciplinary team. Bariatric Times 2006;3:21–2.
27. Wiles CM, Busse ME, Sampson CM, Rogers MT, Fenton-May J, Van Deursen R. Falls and stumbles in myotonic dystrophy. J Neurol Neurosurg Psychiatry 2005;77:393–6. [PubMed: 16199443]
28. Cavanaugh JT, Coleman KL, Gaines JM, Laing L, Morey MC. Using step activity monitoring to characterize ambulatory activity in community-dwelling older adults. J Am Geriatr Soc 2007;55:120–4. [PubMed: 17233695]
29. Gardner AW, Montgomery PS, Afaq A, Blevins SM. Patterns of ambulatory activity in subjects with and without intermittent claudification. J Vasc Surg 2007;46:1208–14. [PubMed: 17919876]
30. Jordan AN, Jurca GM, Locke CT, Church TS, Blair SN. Pedometer indices for weekly physical activity recommendations in postmenopausal women. Med Sci Sports Exerc 2005;37:1627–32. [PubMed: 16177618]
31. Sugiura H, Kajima K, Mirbod SM, Iwata H, Matsuoka T. Effects of long-term moderate exercise and increase in number of daily steps on serum lipids in women: randomized controlled trial. BMC Womens Health 2002;2:3. [PubMed: 11846892]
32. Tudor-Locke C, Bell RC, Myers AM, Harris SB, Ecclestone NA, Lauzon N, et al. Controlled outcome evaluation of the First Step Program: a daily physical activity intervention for individuals with type II diabetes. Int J Obes Relat Metab Disord 2004;28:113–19. [PubMed: 14569279]
33. Tudor-Locke C, Bassett DR Jr, Rutherford WJ, Ainsworth BE, Chan CB, Croteau K, et al. BMI-referenced cut points for pedometer-determined steps per day in adults. J Phys Act Health 2008;5 (Suppl 1):S126–S139. [PubMed: 18364517]
34. Bennett GG, Wolin KY, Puleo E, Emmons KM. Pedometer-determined physical activity among multiethnic low-income housing residents. Med Sci Sports Exerc 2006;38:763–73.
35. Tudor-Locke CE, Bell RC, Myers AM, Harris SB, Lauzon N, Rodger NW. Pedometer-determined ambulatory activity in individuals with type 2 diabetes. Diabetes Res Clin Pract 2002;55:191. [PubMed: 11850095]
36. Tudor-Locke C, Ainsworth BE, Whitt MC, Thompson RW, Addy CL, Jones DA. The relationship between pedometer-determined ambulatory activity and body composition variables. Int J Obes 2001;25:1571–8.
37. Tudor-Locke C, Ham SA, Macera CA, et al. Descriptive epidemiology of pedometer-determined physical activity. Med Sci Sports Exerc 2004;31:91–100.
38. Wyatt HR, Peters JC, Reed GW, Barry M, Hill JO. A Colorado statewide survey of walking and its relation to excessive weight. Med Sci Sports Exerc 2005;37:724–30. [PubMed: 15870624]
39. Simpson M, Serdula M, Galuska DA, et al. Walking trends among U.S. adults: the behavioral Risk Factor Surveillance System, 1987-2000. Am J Prev Med 2003;25:95–100. [PubMed: 12880875]

Table 1

Demographic and Anthropometric Characteristics of LABS-2 Participants by Physical Activity Assessment Status

Characteristic	Total (N=1343)		Included in PA assessment No (N=586)		Yes (N=757)		
	N	**mean± SD**	**N**	**mean± SD**	**N**	**mean± SD**	**p***
Age (years)	1332	44.4±11.1	578	44.2±10.8	754	44.6±11.2	.52
missing	11		8		3		
BMI (kg/m^2)	1337	47.8±7.9	581	48.4±8.2	756	47.4±7.6	.03
missing	6		5		1		
	N	**%**	**N**	**%**	**N**	**%**	**p****
Race							.13
missing	11		4		7		
White	1157	86.9	494	84.9	663	88.4	
Black	127	9.5	66	11.3	61	8.1	
Other	48	3.6	22	3.8	26	3.5	
Hispanic	73	5.4	29	5.0	44	5.8	.49
missing	3		2		1		
Male	281	21.0	128	21.9	153	20.2	.46
missing	2		1		1		
Married/living as married	783	62.2	314	59.9	469	63.9	.15
missing	85		62		23		
Education level							.18
missing	84		63		21		
Some high school	45	3.6	24	4.6	21	2.9	
High school diploma or GED	247	19.6	102	19.5	145	19.7	
Some college	514	40.8	221	42.3	293	39.8	
College diploma	268	21.3	97	18.5	171	23.2	
Graduate/professional degree	185	14.7	79	15.1	106	14.4	
Employed full-time for pay	743	59.2	291	55.6	452	61.7	.03
missing	88		63		25		
Household income							.03
missing	112		73		39		
<$25,000	236	19.2	120	23.4	116	16.2	
$25,000-$49,000	323	26.2	133	25.9	190	26.5	
$50,000-$74,999	294	23.9	112	21.8	182	25.3	
$75,000-$99,999	183	14.9	69	13.5	114	15.9	
≥$100,000	195	15.9	79	15.4	116	16.1	

* T-test. Log of BMI was used in t-test to meet assumption of normality.

** Chi Square test.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 2

Physical Activity Measures by BMI group

	Total (756)		BMI groups (kg/m^2) <40 (117)		40 to < 50 (402)		50 to < 60 (183)		60+ (54)	
Mean steps/day, mean± SD	7569±3159		8566.3±2936		8102±3154		6600±2611		4748±2319	
Activity categories	%	N	%	N	%	N	%	N	%	N
Sedentary <5000 steps/day	20.0	151	10.3	12	13.4	54	29.0	53	59.3	32
Low active 5000-7499 steps/day	33.9	256	27.4	32	33.8	136	40.4	74	25.9	14
Somewhat active 7500-9999 steps/day	26.6	201	30.8	36	30.6	123	19.7	36	11.1	6
Active 10000-12499 steps/day	13.5	102	23.9	28	14.4	58	7.7	14	3.7	2
Highly Active ≥12500 steps/day	6.1	46	7.7	9	7.7	31	3.3	6	0.0	0
Peak activity index,* mean± SD	72.4±15.4		77.1±15.1		74.9±14.4		68.2±14.7		57.1±13.5	

*Mean steps per minute during the most active 30 minutes of the day.