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Objectively-Measured Sedentary Time and Cardiometabolic Health in Adults with Severe Obesity

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Abstract

It is unknown whether sedentary behavior is independently associated with the cardiometabolic health of adults with severe obesity. Additionally, there is debate regarding how best to derive meaningful indices of sedentary time (ST) from activity monitor data. A convenience sample of adults with severe obesity (N=927; 79% female, median age 45y, median body mass index (BMI) 46 kg/m²) completed a research assessment at one of ten US hospitals in 2006-2009 prior to bariatric surgery. Cardiometabolic health was assessed via physical measures, fasting blood samples and medication use. Indices of ST were derived from StepWatch™ activity monitor data with minimum bout durations of 1 min, 10 min and 30 min. Cross-sectional associations were examined. Median (25th, 75th percentile) ST was 9.3 hr/d (8.1, 10.5) in 1 min bouts, 6.5 hr/d (5.2, 8.0) in 10 min bouts, or 3.2 hr/d (2.1, 4.5) in 30 min bouts. Associations with ST were generally strongest with the 10 min bout duration. Independent of moderate-to-vigorous intensity physical activity, BMI and other potential confounders, 1 hr/day ST in 10 min bouts was associated with higher odds of diabetes by 15% (95%CI: 1.05-1.26), metabolic syndrome by 12% (95%CI: 1.01-1.24) and elevated blood pressure by 14% (95%CI: 1.02-1.26), and was associated with 1.4 cm (95%CI: 0.9-1.9) larger waist circumference. Findings indicate the importance of considering ST as a distinct health risk among adults with severe obesity, and suggest a 10 min minimum duration may be preferable to 1 min or 30 min for establishing ST from activity monitor data.

Keywords

sedentary bout length; sedentary lifestyle; physical activity; ambulatory monitoring; methods; metabolic syndrome X; diabetes mellitus; type 2; risk factors; obesity

Physical activity (PA) is well recognized as an important contributor to cardiometabolic health. In particular, participation in moderate-to-vigorous intensity physical activity (MVPA) has been shown to improve blood pressure, lipid profile and glycemic control (1), and play an important role in weight maintenance (2), making MVPA central to guidelines

for the prevention and management of heart disease and type 2 diabetes (3). There is mounting evidence that sedentary behavior, i.e., prolonged sitting or reclining characterized by very low energy expenditure, may also play an important role in cardiovascular and metabolic health, independent of participation in MVPA (4-6).

In the United States, 15% of the adult population has severe obesity, defined as body mass index (BMI) ≥ 35 kg/m² (8). Those affected generally have difficulty meeting MVPA recommendations (9) and are at high risk of cardiovascular and metabolic disease, and premature mortality (10;11). Thus, determining whether sedentary behavior is related to the cardiometabolic health in this population could have important implications for PA recommendations, which currently do not include goals specific to sedentary behavior (1;9).

The majority of studies establishing associations between sedentary behavior and cardiometabolic health have relied on self-report questionnaires (4), which are prone to social desirability and recall bias. Over the last few years, studies utilizing activity monitor data to objectively-measure ST have provided initial evidence that ST is associated with composite and individual measures of poor cardiometabolic health in a variety of populations (5;12-15). However, there is debate regarding the most appropriate way to derive meaningful indices of ST from activity monitor data (5;14). Recent laboratory-based studies show that interrupting prolonged bouts of sedentary behavior with brief PA breaks (e.g. walking at low or moderate intensity for 1-5 minutes) can have acute beneficial effects on blood pressure, and lipid and glucose metabolism (6;7), suggesting the duration of sedentary bouts is a key element to consider. However, most studies employing activity monitors to measure ST have counted all minutes below a set threshold indicative of very low energy expenditure (e.g., <1.5 metabolic equivalents, <100 activity counts) or lack of ambulatory activity (e.g., <1 step) as ST, allowing sedentary bouts to be as short as 1 minute (5). Kim et al. recently investigated the effect of applying various minimum duration requirements, ranging from 1 minute to 30 minutes, to ST (14). They found that more ST accumulated in bouts of <5 minutes was associated with lower cardiovascular risk (i.e., smaller waist circumference, higher high-density lipoprotein (HDL) cholesterol and lower triglycerides), while more ST accumulated in bouts ≥ 10 minutes was associated with higher risk, highlighting the importance of considering duration when defining ST.

To date, no studies have investigated the association between ST and cardiometabolic health in adults with severe obesity. The present investigation aimed to fill this gap by examining associations between activity monitor-derived ST with cardiometabolic health, among adults with severe obesity prior to undergoing bariatric surgery. In response to recommendations for continued research on definitions and measurement of ST (16), three minimum bout duration thresholds (1 minute, 10 minutes and 30 minutes) were applied to ST and examined with respect to the metabolic syndrome, its components, and diabetes.

Methods

Study design and study sample

Adults preparing to undergo their first bariatric surgical procedure were recruited at 10 centers throughout the United States to participate in the Longitudinal Assessment of

Bariatric Surgery-2 (LABS-2) study between February 2006 and February 2009, resulting in a cohort of 2458. The Institutional Review Boards at each center approved the protocol and consent forms. The LABS-2 study is registered at ClinicalTrials.gov (NCT00465829).

The study reported here is cross sectional utilizing data from the baseline research assessment which was conducted by trained research personnel prior to surgery. The analysis sample is a convenience sample of 927 (37.7%) LABS-2 participants with valid PA data (Figure 1). Participants in this observational study received usual preoperative care which, depending on the center, may have included advice or counseling related to health behaviors, including PA. However, patients were not required to change their PA level in preparation for surgery.

Cardiometabolic Health

Waist circumference was measured twice while the participant was standing using the Gulick II Tape Measure (model 67020, Gays Mill, Wisconsin). The measurement was taken around the abdomen horizontally at the midpoint between the highest point of the iliac crest (hip bone) and lowest part of the costal margin (ribs). A single measurement of systolic and diastolic blood pressure (SBP and DBP, respectively) was obtained using a Welch Allyn Spot Vital Signs monitor (model 4200B, Welch Allyn, Skaneateles Falls, New York) after a seated rest of at least five minutes, with no caffeine or nicotine intake for at least 30 minutes. Arm circumference was measured to ensure appropriate cuff size was utilized. The therapeutic class(es) of reported prescription medications was used to determine whether participants were on anti-hypertensive, anti-hyperlipidemic or anti-diabetic medication.

Triglycerides, HDL cholesterol and plasma glucose and glycated hemoglobin A1c (HbA1c) were measured by the Northwest Lipid Metabolism and Diabetes Research Laboratories (Seattle, WA). Triglycerides and glucose are only reported for fasting (8 hours) samples. However, because glucose and triglyceride are higher in a non-fasting state, when fasting values were not available, non-fasting values below thresholds (specified below) were used to categorize participants as not having elevated glucose or elevated triglycerides, respectively.

Per updated National Cholesterol Education Program criteria (17) participants were classified as having metabolic syndrome if three or more of the following criteria were met: (1) central obesity: waist circumference >88 cm for females, >102 cm for males; (2) elevated triglycerides: triglyceride 150 mg/dL or anti-hyperlipidemic medication use; (3) low HDL: HDL <50 mg/dL for females, <40 mg/dL for males; (4) elevated blood pressure: SBP 130 or DBP 85 mm Hg or anti-hypertensive medication use; or (5) elevated glucose: glucose 100 mg/dL or anti-diabetic medication use.

Diabetes was defined as taking diabetes medication or having HbA1c 6.5%, or if HbA1c was not available, glucose 126 mg/dL. Women taking only metformin as a diabetes medication who reported having polycystic ovarian syndrome and who did not meet laboratory criteria for diabetes were not considered to have diabetes.

Activity monitor-based ST

The StepWatch™ 3 activity monitor (OrthoCare Innovations, Washington, D.C.) is a small lightweight microprocessor-controlled biaxial activity monitor, worn above the ankle that combines acceleration, position, and timing information to count strides (i.e. single leg-steps). It is accurate in individuals who are lean or obese with a variety of gait styles at “slow” (i.e., 1.6 km/h) through “fast” (i.e., 5.6 km/h) speeds, with accuracy typically exceeding 98% (18-20). The monitor was programmed to double count strides (to record steps) in 1 minute intervals with sensitivity settings appropriate to a participant's height, gait, and cadence using accompanying software during monitor initialization (19). Eligible participants (i.e., not excluded per Figure 1) were asked to wear the monitor for the seven consecutive days following their research assessment or until the day of surgery, whichever came first. Participants were given the option to remove the waterproof monitor during water-based activities or sleeping.

Steps per minute (cadence) data from StepWatch™ version 3.2 software (OrthoCare Innovations, Washington, D.C.) were exported to a SAS dataset, version 9.3 (SAS Institute Inc, Cary, NC). Sleep and non-wear periods were identified by intervals of at least 120 minutes with 0 steps (21). After removing sleep and non-wear periods, ST, defined as minutes with a step count of 0 (20;22), was calculated for each valid day (i.e., at least 10 hours of awake wear time) with minimum bout durations of 1 minute (1 min), 10 minutes (10 min), and 30 minutes (30 min). ST was then averaged across valid days. ST was standardized to a common wear time by multiplying ST by the ratio of the mean monitor wear time for the entire sample to an individual's monitor wear time. This allowed ST to be adjusted for wear time while still represented in the metric of minutes (23). Participants with at least three valid days of PA assessment were included in the analysis.

Potential confounders

Age, sex, race, ethnicity, marital status, education, employment status, household income, smoking status and regular alcohol consumption (2 drinks/week) were assessed by questionnaire (24). Depressive symptoms over the past week were measured with the Beck Depression Inventory, version 1 (25). A score of 10 or higher indicates at least mild depressive symptoms. With bare feet and in lightweight clothing participants' weight was measured to the nearest pound and height was measured to the nearest inch, then converted to kilograms and meters. BMI was calculated as weight divided by height squared (kg/m^2).

Daily minutes of MVP A was estimated with the StepWatch™. A cadence >80 steps/minute was selected to identify MVP A based on prior work which has shown 1) that healthy adults achieve moderate intensity (defined as 3 standard metabolic equivalents) at a cadence of approximately 100, walking at speeds of 0.9-1.2 m/s (or 2.0-2.7 mph) (26), and 2) adults with obesity achieve a higher activity intensity vs. adults of normal weight when walking at speeds within this range (27). Given the possibility that a threshold of >80 steps/minute might misclassify some moderate-intensity PA as light-intensity PA, a less conservative threshold of >60 steps/minute (28) was applied in a sensitivity analysis. Bouted MVPA, defined as 10 or more consecutive MVPA minutes, with allowance for interruptions of no more than 2 minutes below the MVPA threshold, was also calculated.

Analysis—Analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC). Those excluded from the analysis sample were compared to those included using the chi square test for categorical variables or the Wilcoxon rank sum test for continuous variables. Generalized linear mixed models with the log odds of outcome were used to examine the associations of ST indices (with minimum bout durations of 1 min, 10 min or 30 min) with presence or absence of the metabolic syndrome, each of its components, and diabetes. Since all participants met the central obesity criterion for the metabolic syndrome, separate linear mixed models were used to examine associations of ST indices with waist circumference. Correlation among patients in the same site was accounted for by the inclusion of different random intercepts for sites. All models adjusted for site, sex, age, household income, smoking status, regular alcohol use, depressive symptoms, BMI and MVPA, with the exception that the model of waist circumference was not adjusted for BMI due to the collinearity between these measures. A sensitivity analysis replaced MVPA with minutes at a cadence >60. Models did not adjust for bouts MVPA due to low participation. Two-way interactions between ST and covariates were tested. Statistical significance was set at two-sided $p < 0.05$. Because this was an exploratory analysis, adjustment was not made for multiple outcomes. Adjusted odds ratios (OR), beta coefficients (β) and corresponding 95% CI are presented.

Results

Participant Characteristics

Table 1 shows the characteristics of LABS-2 participants included in and excluded from the analysis sample. Of the 1531 LABS-2 participants excluded, approximately three-fourths were not eligible for PA assessment due to unavailability of activity monitors (a result of budget constraints) or insufficient time to measure PA prior to surgery (Figure 1). Prevalence of non-white race, income <\$25,000, and severe walking limitations was lower in the analysis sample vs. those excluded, while prevalence of full-time employment was higher; there were no other significant differences between groups (Table 1). More than three-fourths of participants had the metabolic syndrome and almost one-third of participants had diabetes.

ST and MVPA

Activity monitor data of participants is shown in Table 2. The majority of participants wore the activity monitor 6 or 7 days and for at least 14 hr/d. Median ST was 9.3 hr/d (65.1% of wear time) in 1 minute bouts, 6.5 hr/d (44.7% of wear time) in 10 minute bouts, or 3.2 hr/d (22.0% of wear time) in 30 minute bouts. The top quartile spent at least 8 hr/d in sedentary bouts 10 minutes, while the bottom quartile spent approximately 5 hr/d or less in sedentary bouts 10 minutes. Participation in MVPA was low, particularly bouts MVPA. Less than one-third of participants (32.9%; $n=305$) engaged in any bouts MVPA and among those who did, the median (25th, 75th percentile) was only 5 (2, 12) min/d. When the less conservative threshold of >60 steps/minute was applied, still only half of participants (50.1%; $n=464$) engaged in any bouts activity, with median (25th, 75th percentile) of 6 (3, 12) min/d.

Associations between ST and Cardiometabolic Health

Table 3 shows the associations between ST indices with varying minimum bout requirements (1 min, 10 min and 30 min), per 1 hour/day ST, and cardiometabolic outcomes. There were no significant interactions between ST indices and MVPA. Controlling for MVPA, BMI and other potential confounders, more ST 1 min was significantly associated with greater odds of metabolic syndrome, low HDL cholesterol, elevated blood pressure and elevated fasting glucose, and larger waist circumference. An interaction between ST 1 min and age indicated that the odds of low HDL associated with ST was higher in older vs. younger adults. More ST 10 min was independently associated with greater odds of metabolic syndrome, elevated blood pressure, diabetes and larger waist circumference. Although ST 30 min followed the same trends as ST 1 min and ST 10 min (i.e., all estimated odds ratios >1), only associations with diabetes and waist circumference were significant.

Associations between ST indices and metabolic syndrome and diabetes, standardized per interquartile range of ST, are shown in Figure 2. The odds of metabolic syndrome and diabetes attributed to ST was greatest with the bout requirement 10 min (OR=1.34 (95% CI: 1.03-1.68) and OR=1.42 (95% CI: 1.14-1.74), respectively). Likewise, the beta coefficient for waist circumference was largest per IQR of ST 10 min (β =4.0 cm (95% CI: 2.6-5.4)) vs. of ST 1 min (β =2.9 cm (95% CI: 1.7-4.2)) or ST 30 min (β =3.1 cm (95% CI: 1.8-4.4)).

Sensitivity analysis

Some associations between ST indices with cardiometabolic outcomes were slightly attenuated when minutes at a cadence >60 replaced MVPA (Supplemental Table 1). Associations between ST indices with low HDL, fasting glucose, diabetes and waist circumference remained statistically significant (p for all <.05), while association with metabolic syndrome and elevated blood pressure did not (p for all >.05).

Discussion

Independent of BMI, MVPA and additional confounders, objectively-measured indices of ST were associated with greater odds of metabolic syndrome, low HDL, elevated blood pressure, elevated fasting glucose and diabetes, as well as larger waist circumference in a large sample of adults with severe obesity prior to undergoing bariatric surgery. These findings indicate the importance of investigating ST as a distinct health risk behavior, not simply lack of MVPA, among adults with severe obesity, which may ultimately inform PA recommendations for this special population.

Our finding that objectively-measured ST (1 min or 10 min), independent of MVPA, was associated with metabolic syndrome, has also been reported in cross-sectional studies among healthy middle-age Japanese adults (29), Australian adults without diabetes (30), and older U.S. adults (31). In contrast, a study among Flemish adults, which reported high levels of total and bouts MVPA, found that ST was not independently associated with metabolic syndrome or its components after controlling for MVPA (32). A potential explanation for

this discrepancy is that high levels of MVPA reduce the effect of sedentary behavior. Findings from a meta-analysis of studies utilizing self-reported PA supports this hypothesis; the risk of all-cause mortality associated with ST was greater among those with low vs. high PA (4). To date such evidence from studies with activity monitor-derived ST is lacking. Although interactions between indices of ST and MVPA were not significant in the current study, it is possible that greater participation in MVPA than was observed is required to mitigate the effect of ST.

The significant association we reported between ST (10 min or 30 min) and prevalent diabetes is supported by findings from a meta-analysis of 10 longitudinal studies, which found that self-reported ST predicted risk of incident diabetes (33). However, a recent study of U.S. adults with activity monitor-derived ST which found a significant associations between ST (1 min) and diabetes in cross sectional analysis, but not in longitudinal analysis (i.e., baseline ST did not predict 5 year incident prediabetes or diabetes) (16), suggests more research is needed to establish ST as a predictor of metabolic disease.

While few studies have evaluated associations between objectively-measured ST and components of the metabolic syndrome, several studies have evaluated associations with waist circumference, triglycerides, HDL cholesterol, SBP and fasting glucose. The majority of studies support unfavorable associations with waist circumference (34-38) and triglycerides (5), while evidence of an association with HDL cholesterol is inconclusive (5), and evidence of an association with SBP (5;30;34;35;39;40) or fasting plasma glucose (5) is lacking. Thus, some of our findings are in agreement with previous work, while others conflict with the majority of prior research. Given that several associations with ST differed within our study by the minimum duration threshold used to establish ST, it is likely that differences in assessment (e.g., waist-worn accelerometer vs. StepWatch) and definitions of ST account for at least some of the discrepancies across studies. Differences in control for confounders and populations may also contribute to disparate findings.

In line with the study by Kim et al. (15) (described in the introduction), the findings presented here suggest a minimum duration of 10 minutes is preferable to 1 or 30 minutes for establishing ST, in relation to most measures of cardiometabolic health. For example, in the present study both ST 1 min and ST 10 min, but not ST 30 min, were significantly associated with metabolic syndrome and some of its components, while ST 10 min and ST 30 min, but not ST 1 min, were both associated with diabetes. In addition, ST 10 min had the strongest association with metabolic syndrome, diabetes and waist circumference. A potential explanation for this finding is that applying a threshold of 30 min to establish ST misclassifies a substantial portion of ST that is detrimental to health. Although most studies examining activity monitor-derived ST and cardiometabolic health have considered all minutes below a specified threshold as SB, a recent study by Healy et. al, examined ST <30min and ST 30 min separately among adults with overweight/obesity and diabetes (14). ST 30 min, but not MVPA or ST <30min, was significantly associated with both waist circumference and BMI. In addition, isothermal substitution analysis suggested reducing ST 30 min while increasing low-intensity PA might result in clinically-meaningful decreases in waist circumference and BMI. Meanwhile, neither ST (<30 min or 30 min) nor MVPA were associated with SBP, DBP, HDL-cholesterol, triglycerides or fasting

glucose. These findings suggest additional work is warranted to refine the minimum threshold requirement for ST.

To address the fact that the threshold used to identify MVPA among adults with severe obesity in this study (i.e., cadence >80) might have underestimated MVPA, a sensitivity analysis was employed which replaced MVPA with minutes at a cadence greater than 60. While some associations between ST indices with cardiometabolic outcomes were slightly attenuated, most were largely unaffected. Thus, our results imply that cardiometabolic health of adults with severe obesity might be improved by replacing sedentary behavior with low-intensity PA, whether defined as a cadence of 80 or 60.

When interpreting this study's results, several limitations should be considered. First, temporal relationships between ST with cardiometabolic health cannot be established from this cross sectional analysis. However, establishing associations is an important precursor to investment in clinical trials which can test causality. Additionally, study participants were a convenience sample of adults undergoing bariatric surgery. While minor differences were detected between those included and excluded from the analysis sample, it is unlikely these factors influenced the associations evaluated in this report. Finally, the StepWatch, selected for its accuracy in measuring PA of adults with severe obesity, was the only activity monitor employed in this study. Thus, ST was based on an estimate of time spent not ambulating (i.e. generating 0 steps) and did not take posture into account. Future studies should consider postural sensors to reduce misclassification.

Major strengths of this study are 1) the large geographically diverse sample; 2) the objective assessment of ST, and evaluation of three minimum durations to establish ST; and 3) adjustment for both MPVA and BMI, enabling examination of whether ST, over and above MVPA and obesity severity, may contribute to poor cardiometabolic health.

Conclusion

Our study demonstrates that ST, independent of MVPA, is associated with several markers of cardiometabolic health, among adults with severe obesity prior to bariatric surgery. These findings suggest that cardiometabolic health may be improved by replacing sedentary behavior with low-intensity PA. Future work should investigate whether intervening on sedentary behavior is an effective approach to cardiovascular and metabolic disease prevention and management among adults with severe obesity, to inform PA recommendations. In addition, this study suggests a minimum duration of 10 minutes may be preferable to 1 minute or 30 minutes for identifying ST from activity monitor data, and confirms the need for future research to consider duration when defining activity monitor-derived ST.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

PA	Physical activity
ST	Sedentary time
LABS-2	Longitudinal Assessment of Bariatric Surgery-2

Highlights

- Sedentary time (ST) is associated with cardiometabolic health of obese adults
- This is true after control for physical activity and additional confounders
- The duration threshold for activity monitor-derived ST impacts associations
- A threshold of 10 minutes may be preferable to 1 minute or 30 minutes

Figure 1.

Baseline Physical Activity Assessment in the LABS-2 Study, 2006-2009.

Footnote: LABS-2=Longitudinal Assessment of Bariatric Surgery-2

Figure 2.

Forest Plot showing the adjusted odds ratios^a and 95% confidence intervals of associations between sedentary time indices, per IQR, and metabolic syndrome and diabetes among a US sample of adults with severe obesity prior to undergoing bariatric surgery at one of ten US hospitals, 2006-2009.

Footnote: IQR=interquartile range, CI=confidence interval, ST=Sedentary Time

^aAdjusted for site, sex, age, household income, smoking status, regular alcohol use, depressive symptoms, BMI and MVPA.

^b149 min for ST ≥ 1 min, 171 min for ST ≥ 10 min and 144 min for ST ≥ 30 min.

Table 1

Characteristics of adults with severe obesity participating in the LABS-2 study, prior to undergoing bariatric surgery at one of ten US hospitals, 2006-2009.

	Analysis Sample (n=927)		Excluded (N=1531)	
	N ^a	n (%) or median (25 th , 75 th percentile) ^b	N ^a	n (%) or median (25 th , 75 th percentile) ^b
<i>Sociodemographics</i>				
Female	927	733(79.1)	1531	1198(78.2)
Age, years	927	45(36,54)	1531	46(37,54)
Race *	919		1514	
White		814(88.6)		1288(85.1)
Black		79(8.6)		177(11.7)
Other		26(2.8)		49(3.2)
Hispanic/Latino ethnicity	927	54(5.8)	1529	65(4.3)
Married or living as married	895	572(63.9)	1369	872(63.7)
Education	895		1369	
High school or less		189(21.1)		332(24.3)
Some college		359(40.1)		559(40.8)
College degree		347(38.8)		478(34.9)
Employed full-time ****	893	662(74.1)	1364	889(65.2)
Household income **	875		1329	
<\$25,000		128(14.6)		274(20.6)
\$25,000-\$49,000		234(26.7)		334(25.1)
\$50,000-\$74,999		227(25.9)		295(22.2)
\$75,000-\$99,999		143(16.3)		210(15.8)
\$100,000		143(16.3)		216(16.3)
<i>Health behavior/status</i>				
Current or recent smoker	924	126(13.6)	1530	198(12.9)
Regular alcohol use	900	51(5.7)	1362	95(7.0)
Body Mass Index, kg/m ²	927	45.8(41.9,51.3)	1531	46.0(41.7,51.5)
Depressive symptoms	905	295(32.6)	1458	452(31.0)
Severe walking limitation ****	809	30(3.7)	1439	123(8.5)
<i>Cardiometabolic health</i>				
Metabolic Syndrome	840	647(77.0)	1269	991(78.1)
Central obesity	891	891(100.0)	1531	1531(100.0)
Elevated triglycerides	861	343(39.8)	1330	527(39.6)
Low high-density lipoprotein	918	605(65.9)	1466	991(67.6)
Elevated blood pressure	919	708(77.0)	1497	1198(80.0)
Elevated fasting glucose	900	491(54.6)	1434	776(54.1)
Diabetes	903	285(31.6)	1411	489(34.7)
Waist circumference, cm	891	130.2(120.5,141.5)	1401	131.5(121.7,143.5)

LABS-2=Longitudinal Assessment of Bariatric Surgery-2

^a N with data for the specified variable.

^b Data not normally distributed.

*
p<0.05;

**
p<0.01;

p<0.001;

p<0.0001.

Table 2

Sedentary behavior and physical activity of adults with severe obesity prior to undergoing bariatric surgery at one of ten US hospitals, 2006-2009.

<i>Physical activity monitor</i>	N=927
	median(25th, 75th percentile) ^c
Valid assessment days	6(5,7)
Monitor wear time, min/d	864(801, 932)
Sedentary time, min/d ^a	
1 min bouts	557(483,632)
10 min bouts	389(309,480)
30 min bouts	190(128,272)
MVPA, min/d ^a	
1 min bouts	9(5,16)
10 min bouts	0(0,2)
Cadence >60 ^b , min/d ^a	
1 min bouts	23(14,36)
10 min bouts	1(0,6)

MVPA= moderate-to-vigorous intensity physical activity.

^a Categories are not mutually exclusive (e.g., 1 min includes 10 min and 30 min).

^b MVPA is defined as minutes with a cadence >80 steps/min. Cadence >60 steps/min is a less conservative threshold to identify potential MVPA utilized in a sensitivity analysis.

^c Data not normally distributed.

Table 3

Associations between sedentary time and metabolic syndrome, its components, diabetes and waist circumference, adjusted for BMI, MVPA and additional confounders^a, among a US sample of adults with severe obesity prior to undergoing bariatric surgery at one of ten US hospitals, 2006-2009.

		Sedentary time per 1 hour/d		
	N	1 minute bout	10 minute bout	30 minute bout
Adjusted odds ratios (95% CI)				
Metabolic syndrome	825	1.13(1.02-1.25)	1.12(1.01-1.24)	1.06(0.94-1.20)
Elevated triglycerides	797	1.06(0.98-1.16)	1.05(0.97-1.15)	1.02(0.93-1.12)
Low HDL cholesterol	845	<i>b</i>	1.03(0.95-1.12)	1.03(0.94-1.13)
At age 36 y		0.96(0.86-1.08)		
At age 45 y		1.05(0.97-1.15)		
At age 54 y		1.15(1.03-1.28)		
Elevated blood pressure	845	1.12(1.01-1.25)	1.14(1.02-1.26)	1.13(0.99-1.28)
Elevated fasting glucose	834	1.10(1.01-1.20)	1.06(0.98-1.16)	1.04(0.94-1.14)
Diabetes	850	1.08(0.99-1.18)	1.15(1.05-1.26)	1.12(1.01-1.23)
Adjusted beta (95% CI)				
Waist circumference (cm) ^C	812	1.18(0.68-1.68)	1.39(0.90-1.89)	1.30(0.75-1.85)

BMI=body mass index; MVPA=moderate-to-vigorous intensity physical activity; HDL=high-density lipoprotein; ST=sedentary time.

^aThe association between each index of ST and each outcome was evaluated in a separate model adjusting for site, sex, age, household income, smoking status, regular alcohol use, depressive symptoms, BMI and MVPA.

^bThere was a significant interaction between age and ST (1 min) ($p=.01$); odds ratios for low HDL are presented at quartiles of age.

^cSince all participants met the central obesity criterion for the metabolic syndrome, the association of ST indices with waist circumference (continuous) was examined.