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Sedentary behavior patterns in non-pregnant and pregnant women

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ABSTRACT

Sedentary behavior has been associated with adverse health outcomes among pregnant women; however, few studies have characterized sedentary behavior patterns in this population. We described patterns of accelerometer-determined indicators of sedentary behavior among a national sample of US pregnant ($n = 234$) women and non-pregnant ($n = 1146$) women participating in the NHANES 2003-06 cycles. We included women with ≥4 days of accelerometer wear of ≥10 h/day. A count threshold of <100 cpm was used to describe sedentary behavior as: 1) total accumulated sedentary time by bout length categories; 2) accumulated sedentary time within discrete bout length categories; 3) mean, median, and usual bout length; and 4) and bout frequency. Both non-pregnant and pregnant women spent up to 60% of their accelerometer wear time in sedentary behavior depending on the minimum bout threshold applied. Sedentary time was higher among pregnant women compared to non-pregnant women when lower bout thresholds (i.e. 10 min or less) were applied. The majority of total sedentary time was accumulated in bouts lasting <10 min. The women averaged less than two prolonged sedentary bouts (i.e., ≥30 min) per day, which accounted for nearly 20% of total accumulated sedentary time. When applying a minimum threshold of at least 15 min, sedentary time increased across pregnancy trimesters, while sedentary time was similar across trimesters when using lower thresholds. These findings provide the first characterization of accelerometer-determined indicators of sedentary behavior in pregnant women. The minimum bout threshold applied influenced estimates of sedentary time and patterns sedentary time accumulation across pregnancy trimesters.

1. Introduction

Sedentary behavior is often characterized as behaviors with low energy expenditure and sitting (Owen et al., 2009). Recently, studies have found that sedentary behavior is associated with cardio-metabolic risk factors and mortality independent of moderate-to-vigorous intensity physical activity in non-pregnant populations (Thorp et al., 2011; Yates et al., 2012; Allison et al., 2012; Tremblay et al., 2010; Healy et al., 2011). Among pregnant women, sedentary behavior has been associated with an increased risk for abnormal glucose tolerance, gestational diabetes, and preeclampsia (Saftlas et al., 2004; Gollenberg et al., 2010; Leng et al., 2016). Unfortunately, few studies have sought to describe patterns of sedentary behavior among pregnant women. In the few studies that have, sedentary behavior was estimated by summing every minute of accelerometer wear registering fewer than 100 counts (Evenson and Wen, 2011). While this approach is common in epidemiological studies, recent research suggests it may be important to consider the bout length in which the sedentary time was accumulated (Kang and Rowe, 2015). For example, Kim et al. examined the association of sedentary behavior accumulated in varying bout lengths with cardiovascular risk factors in US adults (Kim et al., 2015). The authors found that sedentary time accumulated in bouts of ≤5 min were associated with lower levels of cardiovascular risk factors while sedentary time accumulated in bouts of ≥10 min were associated with higher levels of these factors.

In addition to considering bout length, studies suggest that the patterns of sedentary behavior bout frequency are also important (Healy et al., 2011; Larsen et al., 2014; Dunstan et al., 2012). For example, Healy et al. found that individuals that had few breaks in sedentary time had a worse cardio-metabolic profile than people that had many breaks (Healy et al., 2011). Thus, there are several indicators of sedentary

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behavior that can be considered, but most studies only describe the total duration of sedentary behavior and none have been conducted among pregnant women (Diaz et al., 2016; Shiroma et al., 2013). Describing other indicators of sedentary behavior can inform the development of sedentary behavior interventions which may aim to target different sedentary endpoints in this particular population. The purpose of this manuscript was to describe patterns of sedentary behavior among a sample of US non-pregnant and pregnant women by trimester of pregnancy.

2. Methods

2.1. Study population

NHANES is a cross-sectional observational study of non-institutionalized U.S. residents conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention. NHANES uses a stratified, multistage probability sampling design to obtain a nationally representative sample of the US population (National Center for Health Statistics. Survey Design Factors Course, 2011). It oversamples minority subpopulations, including pregnant women during the 2003–2006 cycles, so that nationally representative estimates of the health of these sub-populations can be generated. The NCHS Research Ethics Review Board approved the NHANES protocol, and informed consent was obtained from all participants at the time of household interview.

During NHANES, women who participated in physical examinations and laboratory tests at a mobile examination center (MEC) completed the computer-assisted questionnaire about their reproductive health. Women that self-reported being pregnant were asked the month of pregnancy to determine their trimester.

The current analysis was limited to women aged between 18 and 43 years, in the NHANES 2003–2004 and 2005–2006 study cycles. The final sample included 1146 were non-pregnant and 38, 102, and 94 women in their first, second, and third trimester of pregnancy, respectively, at the time of the interview.

2.2. Sedentary behavior assessment

In the NHANES 2003–2004 and 2005–2006 study cycles, participants with no physical disorders were provided with an ActiGraph accelerometer (model: 7164; ActiGraph, LLC, Pensacola, FL) to wear on the right hip during waking hours for seven consecutive days, removing it only for bathing or water-based activities. The accelerometer was attached to an elastic belt and set to record the magnitude of accelerations in the vertical axis in 60-second epochs. We used the Troiano algorithm to screen for non-wear (Troiano et al., 2008). After removing non-wear periods for each day, sedentary behavior was operationalized as accumulated time <100 counts per minute (cpm) (Troiano et al., 2008), a threshold previously used in studies involving general adult and pregnant populations (Evenson and Wen, 2010; Kim and Chung, 2015). For example, activities such as sitting or standing with little movement would likely accumulate <100 cpm. Participants were included if they had ≥4 days with ≥10 h of wear per day.

To describe accumulated patterns of sedentary time, indicators of sedentary behavior were described as 1) total accumulated sedentary time by bout length categories; 2) accumulated sedentary time within discrete bout length categories; 3) bout length, and 4) and bout frequency. For all sedentary indicators, weekly estimates were used in analysis and computed as the average across the number of valid wear days.

Total accumulated sedentary time by bout length categories was calculated as the sum of sedentary time accumulated in various bout lengths (i.e., ≥1, ≥5, ≥10, ≥15, ≥20, ≥25, and ≥30) reported in average minutes per day and as an average percentage of accelerometer wear time per day.

Accumulated sedentary time within discrete bout length categories was calculated for the following categories: 1–4, 5–9, 10–14, 15–19, 20–24, 25–29, and ≥30 in both average minutes per day and as an average percentage of total sedentary time per day.

Bout length was described as mean, median, and "usual" bout length. We used a technique proposed by Chastin & Granat called sedentary bout half-life ($W_{50\%}$), to calculate "usual" bout length. The methods for calculating sedentary half-life are described in more detail elsewhere (Chastin and Granat, 2010). In brief, sedentary half-life is a function of total sedentary time and bout length. Specifically, it indicates the bout length in which half of total sedentary time is accrued, thereby providing information on *how* sedentary time is accrued (e.g. prolonged bouts versus small bouts). Higher half-life values indicate the accumulation of sedentary time in prolonged bouts.

Bout frequency was described as the total number bouts per day within discrete bout lengths of increasing duration (i.e., 1, 2–4, 5–9, 10–14, 15–19, 20–24, 25–29, and ≥30). Bout frequency provides similar information as sedentary breaks (Kim et al., 2015), however bout frequency may better inform intervention strategies (e.g. targeting total duration or prolonged bouts).

Lastly, coefficient of variations were used to examine the day-to-day variability of indicators of sedentary behavior outlined above, using the daily estimates, across all valid days of wear.

2.3. Covariates

Information on age, race/ethnicity, education, and income was collected through self-report during the household interview. Race/ethnicity data were self-reported and participants were classified as non-Hispanic white, non-Hispanic black, Hispanic, or other (includes multi-racial). Current smoking was defined as a serum cotinine level ≥3 mg/dL. Annual household income was categorized as <$35,000, $35,000 to <$65,000, ≥$65,000, or unknown/missing. Education level was categorized as less than high school, high school diploma or GED, and greater than high school. Parity was determined based on the self-reported number of live births and categorized as 0, ≥1, or unknown/missing. To provide information on pregnancy history, adverse pregnancy outcomes were determined by the self-reported history of low birth weight babies (<5.5 g) or preterm births (<37 weeks gestation) and categorized as 0, ≥1, or an unknown/missing.

2.4. Statistical analysis

The complex survey design used for NHANES data collection was incorporated into all data analysis using the "svy" command in STATA 14.0 (StataCorp LP: College Station, TX) using the appropriate strata clustering and weighting. We used an adjusted survey weight to account for non-compliance with the accelerometer component using R package "nhanesaccel" (Van Domelen et al., 2013). Descriptive characteristics included frequencies and percentages for categorical variables and means and standard deviations for continuous variables. Chi-square or analysis of variance tests were used to compare socio-demographic characteristics between non-pregnant women and in pregnant women by trimester. For the main analysis, multivariate linear regression was used to compare each sedentary behavior pattern between non-pregnant and pregnant women. Next, we tested for linear trends across trimester of pregnancy. All analyses were age-adjusted. For the analysis comparing mean minutes of sedentary behavior across the four groups, we additionally adjusted for total accelerometer wear time. All statistical significance tests were two-sided with the familywise type I error level set at $p < 0.05$.

3. Results

Overall, the sample was young, with pregnant women on average four years younger than non-pregnant women (27.5 years vs.

31.5 years, $p < 0.01$). Pregnant women were more likely to be married, less likely to be current smokers, and had higher annual household incomes than non-pregnant women. There were no other socio-demographic differences between the groups (Table 1). Accelerometer wear time differed between pregnant and non-pregnant women, with non-pregnant women wearing the monitor longer than pregnant women (837.9 min/d vs. 791.0 min/d, $p < 0.01$). Among pregnant women, women in their 2nd trimester of pregnancy wore the monitor longer than women in their 1st or 3rd trimester of pregnancy (811.7 min/d, 782.2 min/d, 770.7 min/d respectively, $p < 0.01$). However, there were no differences in the number of valid days of accelerometer data between pregnant and non-pregnant women (data not shown).

3.1. Total accumulated sedentary time by bout length categories

First, we calculated average minutes per day of total accumulated sedentary time by bout length categories (Table 2). Pregnant women accumulated higher amounts of sedentary time compared to non-pregnant women when a minimum bout length of 1 min was applied. Specifically, pregnant and non-pregnant women averaged 480.4 min/d and 461.2 min/d of sedentary time, respectively ($p = 0.01$) (Table 2). Similar patterns were observed when a minimum bout length of 5 min or 10 min was applied. Sedentary time was similar across pregnancy trimesters when using a minimum bout length <15 min. However, when applying a minimum bout length of 15 min, there was a statistically significant linear trend of higher accumulated sedentary time across trimesters of pregnancy.

We then calculated total accumulated sedentary time as an average percent of total wear time (Table 2). When the minimum 1-min bout length was applied, pregnant women had a higher percentage of waking hours spent sedentary than non-pregnant women (57.3% vs. 55.1%, respectively; $p = 0.03$). Applying a higher minimum bout length threshold resulted in a lower estimate of the percentage of daily hours spent sedentary. For example, with a minimum 10-min bout length applied, non-pregnant and pregnant women spent 28.1% and 30.3% of their waking wear time in sedentary behavior, respectively. Overall, pregnant women spent a higher proportion of waking time sedentary than non-pregnant women when minimum bout lengths of 5 min or less were used. Among pregnant women, the percentage of waking wear time spent sedentary was similar across trimesters when a bout length of ≤20 min was applied. However, when using a bout length of at least 25 min, the percentage of sedentary time per waking hours increased across increasing trimesters (p for linear trend = 0.04).

Regardless of minimum sedentary bout length applied, day-to-day variability in accumulated sedentary time did not differ between non-pregnant and pregnant women. In both non-pregnant and pregnant women, day-to-day variability was highest when a minimum 1-min bout length was applied, gradually decreasing as the minimum bout length threshold increased. Among pregnant women, day-to-day variability in total sedentary time ranged from 1.4% to 11.5% depending on the minimum bout length that was applied and trimester of pregnancy (Table 2). The range of variability across minimum bout length categories, appeared to be highest among women in their first trimester compared to all other groups, including non-pregnant women.

3.2. Accumulated sedentary time within discrete bout length categories

Next, we calculated the duration of sedentary time accumulated within discrete bout lengths categories (Table 3). When compared to non-pregnant women, pregnant women had higher sedentary time within bouts lasting 5–9 min, 10–14 min, and 15–19 min (all $p < 0.05$). There were no other statistically significant differences in the amount of sedentary time accumulated within discrete bout length categories between non-pregnant and pregnant women. In both non-pregnant and pregnant women, the highest percent of sedentary time was accumulated in bout lengths lasting <5 min. Specifically, non-pregnant women and pregnant women accumulated 29% and 27.4% of their total duration of sedentary time in bouts of this length, respectively. Further, approximately 21% of sedentary time was accumulated in bouts lasting between 5 and 9 min in both groups. Among pregnant women, there was a statistically significant linear trend of decreasing time spent sedentary within bout lengths lasting between 5 and 9 min across trimesters of pregnancy. Conversely, the amount of accumulated sedentary time within bouts lasting ≥30 min significantly increased across

Table 1
Descriptive characteristics of non-pregnant and pregnant women by trimester of pregnancy.

	Non-pregnant ($N = 1146$)		1st Trimester ($N = 38$)		2nd Trimester ($N = 102$)		3rd Trimester ($N = 94$)		p-Value[a]
	N	%	N	%	N	%	N	%	
Age (yrs) (mean, SE)	31.56	0.3	27.53	1.0	27.67	0.6	27.22	0.7	<0.01
Race/ethnicity									
Non-Hispanic White	470	41.0	21	55.3	60	58.8	43	45.7	0.74
Non-Hispanic Black	349	30.5	11	28.9	28	27.5	35	37.2	
Hispanic	269	23.5	4	10.5	11	10.8	11	11.7	
Other	58	5.1	2	5.3	3	2.9	5	5.3	
Education									
Less than high school	228	19.9	13	35.1	23	22.5	20	21.3	0.07
High school or GED	263	22.9	6	16.2	19	18.6	20	21.3	
Greater than high school	655	57.2	18	48.6	60	58.8	54	57.4	
Household Income									
<$35,000	442	38.6	18	47.4	35	34.3	32	34.0	<0.01
$35,000 to <$65,000	292	25.5	10	26.3	25	24.5	24	25.5	
≥$65,000	351	30.6	9	23.7	36	35.3	36	38.3	
Unknown	61	5.3	1	2.6	6	5.9	2	2.1	
Married	612	42.2	32	46.4	88	56.8	81	58.3	<0.01
Current Smokers	217	13.8	2	3.2	11	7.3	6	4.5	<0.01
Parity									
0	45	3.9	1	2.6	3	2.9	2	2.1	0.87
≥1	590	51.5	26	68.4	66	64.7	64	68.1	
Unknown/Missing	511	44.6	11	28.9	33	32.4	28	29.8	
History of low birth weight or preterm birth									
0	467	40.8	17	44.7	56	54.9	53	56.4	0.56
>1	459	40.1	18	47.4	39	38.2	37	39.4	
Unknown	220	19.2	3	7.9	7	6.9	4	4.3	

[a] p-Value compares the mean or frequency distribution between each category across trimesters.

Table 2
Total accumulated sedentary time[c] by bout length categories among non-pregnant women and pregnant women by trimester of pregnancy.

	Non-pregnant			Pregnant			1st Trimester			2nd Trimester			3rd Trimester		
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI	
Total Sedentary Time (min/d)															
≥1 min bouts	461.2	453.4	469.0	480.4[a]	453.4	469.0	478.8	444.4	513.2	478.6	464.4	492.9	483.8	453.8	513.8
≥5 min bouts	333.3	324.3	342.3	354.3[a]	337.3	371.2	345.1	299.2	391.0	350.2	334.1	366.2	365.8	331.4	400.3
≥10 min bouts	235.4	226.6	244.3	251.8[a]	235.2	268.4	236.2	190.1	282.3	248.8	232.3	265.2	266.2	232.3	300.1
≥15 min bouts	173.8	165.8	181.8	184.7	170.6	198.9	166.6	124.8	208.4	182.4	167.7	197.2	200.0[b]	172.7	227.3
≥20 min bouts	131.8	124.7	139.0	138.9	126.2	151.7	125.0	90.7	159.3	136.8	124.2	149.4	151.1[b]	127.6	174.7
≥25 min bouts	101.4	95.0	107.7	109.0	99.0	119.0	96.4	70.3	122.4	107.5	95.8	119.1	119.6[b]	99.8	139.4
≥30 min bouts	79.5	74.2	84.8	85.3	76.3	94.3	71.7	49.7	93.7	86.8	76.0	97.6	92.5[b]	75.3	109.7
Total Sedentary Time (% wear time)															
≥1 min bouts	55.1	54.2	56.0	57.3[a]	55.4	59.2	56.9	52.5	61.3	57.0	55.3	58.7	57.9	54.0	61.8
≥5 min bouts	39.8	38.8	40.9	42.2[a]	39.9	44.4	40.6	34.5	46.7	41.6	39.6	43.6	43.9	39.5	48.4
≥10 min bouts	28.1	27.1	29.2	30.0	27.8	32.2	27.6	21.4	33.7	29.6	27.5	31.7	32.2	27.8	36.5
≥15 min bouts	20.8	19.9	21.7	22.0	20.1	24.0	19.3	13.7	24.9	21.7	19.8	23.6	24.3	20.8	27.8
≥20 min bouts	15.8	14.9	16.6	16.5	14.8	18.3	14.4	9.8	19.0	16.2	14.6	17.9	18.4	15.3	21.4
≥25 min bouts	12.1	11.4	12.9	13.0	11.6	14.3	11.1	7.6	14.6	12.7	11.2	14.3	14.5[b]	12.0	17.0
≥30 min bouts	9.5	8.9	10.1	10.1	8.8	11.3	8.1	5.1	11.2	10.3	8.8	11.7	11.1[b]	8.9	13.3
Day-to-day variability (CV%)															
≥1 min bouts	8.7	8.4	9.1	9.7	8.0	11.5	11.4	5.0	17.8	8.6	7.3	9.9	9.9	8.3	11.6
≥5 min bouts	5.1	4.9	5.3	5.8	4.5	7.1	7.0	1.9	12.1	5.3	4.3	6.2	5.7	4.9	6.6
≥10 min bouts	3.5	3.3	3.7	3.8	3.2	4.4	3.7	2.0	5.4	3.6	2.9	4.2	4.2	3.3	5.2
≥15 min bouts	2.6	2.4	2.7	3.0	2.4	3.6	3.4	1.1	5.7	2.6	2.2	3.0	3.3	2.5	4.2
≥20 min bouts	2.0	1.9	2.1	2.2	2.0	2.6	2.2	1.3	3.1	2.2	1.7	2.6	2.5	2.0	3.0
≥25 min bouts	1.7	1.6	1.8	1.9	1.6	2.1	1.9	1.2	2.6	1.7	1.4	2.1	2.1	1.7	2.5
≥30 min bouts	1.4	1.3	1.5	1.6	1.3	1.8	1.7	0.8	2.7	1.4	1.3	1.6	1.7	1.4	2.0

[a] Statistically significant differences compared with non-pregnant women.
[b] Statistically significant linear trend among pregnant women.
[c] All estimates are adjusted for age; total sedentary time (min/d) additionally adjust for wear time.

trimesters (p for linear trend <0.05). These same linear trends across pregnancy trimesters were observed when estimates reflecting the percentage of accumulated sedentary time within discrete bout lengths as a function of total sedentary time were used.

Overall, the day-to-day variability in sedentary time accumulated within discrete bouts ranged between 0.9% and 4.8%. There were no statistically significant differences in day-to-day variability between non-pregnant and pregnant women pregnancy regardless of minimum bout length used. Among pregnant women, there were no statistically significant differences in the day-to-day variability across trimesters of pregnancy, except for time accumulated in bouts lasting 20–25 min. Specifically, we observed a small increase in day-to-day variability from 0.9% to 1.2% from first to third trimester (Table 3).

3.3. Bout length

Overall, there were no statistically significant differences in mean, median or usual sedentary bout length between non-pregnant and pregnant women Mean, median and usual bout length was approximately 5 min, 2 min, and 10 min respectively. There were no statistically significant differences in mean or median bout lengths across trimesters of pregnancy; however, there was a statistically significant linear trend of higher usual bout length values across trimesters of pregnancy (p for linear trend = 0.03) (Fig. 1).

The day-to-day variability in mean and median bout length ranged between 20% and 26.9%. The variability in usual bout lengths was higher, ranging from 31.3% to 36.9%. There were no differences in day-

Table 3
Accumulated sedentary time[c] within discrete bout length categories among non-pregnant women and pregnant women by trimester of pregnancy.

	Non-pregnant			Pregnant			1st Trimester			2nd Trimester			3rd Trimester		
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI	
Time in Specific Bout Length (% total sedentary time)															
1 to 4 min bouts	29.0	28.2	29.7	27.4	25.5	29.3	29.7	23.9	35.5	27.6	25.8	29.4	25.2	21.5	28.9
5 to 9 min bouts	21.4	21.0	21.8	21.6[a]	20.7	22.5	23.2	21.2	25.1	21.3	20.2	22.4	20.7[b]	19.1	22.4
10 to 14 min bouts	13.2	13.0	13.4	13.8[a]	13.1	14.5	14.4	13.3	15.6	13.7	12.7	14.8	13.4	12.1	14.6
15 to 19 min bouts	8.9	8.7	9.1	9.4[a]	8.8	10.0	8.4	6.7	10.0	9.4	8.5	10.3	10.1	9.1	11.1
20 to 24 min bouts	6.5	6.3	6.7	6.0	5.3	6.7	5.6	3.7	7.5	6.0	5.3	6.7	6.4	5.5	7.4
25 to 29 min bouts	4.6	4.3	4.8	4.9	4.4	5.4	5.1	4.1	6.0	4.2	3.7	4.7	5.7	4.6	6.8
> 30 min bouts	16.5	15.6	17.3	16.9	15.1	18.8	13.7	9.3	18.1	17.8	15.4	20.2	18.5[b]	15.5	21.6
Day-to-day variability (CV%)															
1 to 4 min bouts	4.2	4.1	4.4	4.2	3.6	4.8	4.2	3.2	5.1	4.2	3.3	5.2	4.2	3.5	4.8
5 to 9 min bouts	4.2	4.0	4.3	4.7	4.1	5.2	4.8	3.6	6.1	4.7	3.9	5.4	4.6	3.7	5.5
10 to 14 min bouts	2.6	2.6	2.7	3.0	2.6	3.5	3.3	2.0	4.7	3.1	2.5	3.7	2.7	2.2	3.1
15 to 19 min bouts	1.8	1.7	1.9	2.0	1.7	2.4	2.6	0.9	4.2	1.9	1.5	2.2	1.9	1.7	2.1
20 to 24 min bouts	1.3	1.2	1.4	1.4	1.2	1.6	1.3	0.9	1.7	1.3	1.1	1.5	1.5	1.2	1.8
25 to 29 min bouts	0.9	0.9	1.0	1.0	0.9	1.1	0.9	0.8	1.1	0.9	0.8	1.0	1.2[b]	1.0	1.4
≥ 30 min bouts	1.5	1.4	1.6	1.7	1.4	2.0	1.9	0.8	2.9	1.5	1.4	1.7	1.8	1.4	2.1

[a] Statistically significant difference compared with non-pregnant women.
[b] Statistically significant linear trend among pregnant women.
[c] All estimates are adjusted for age.

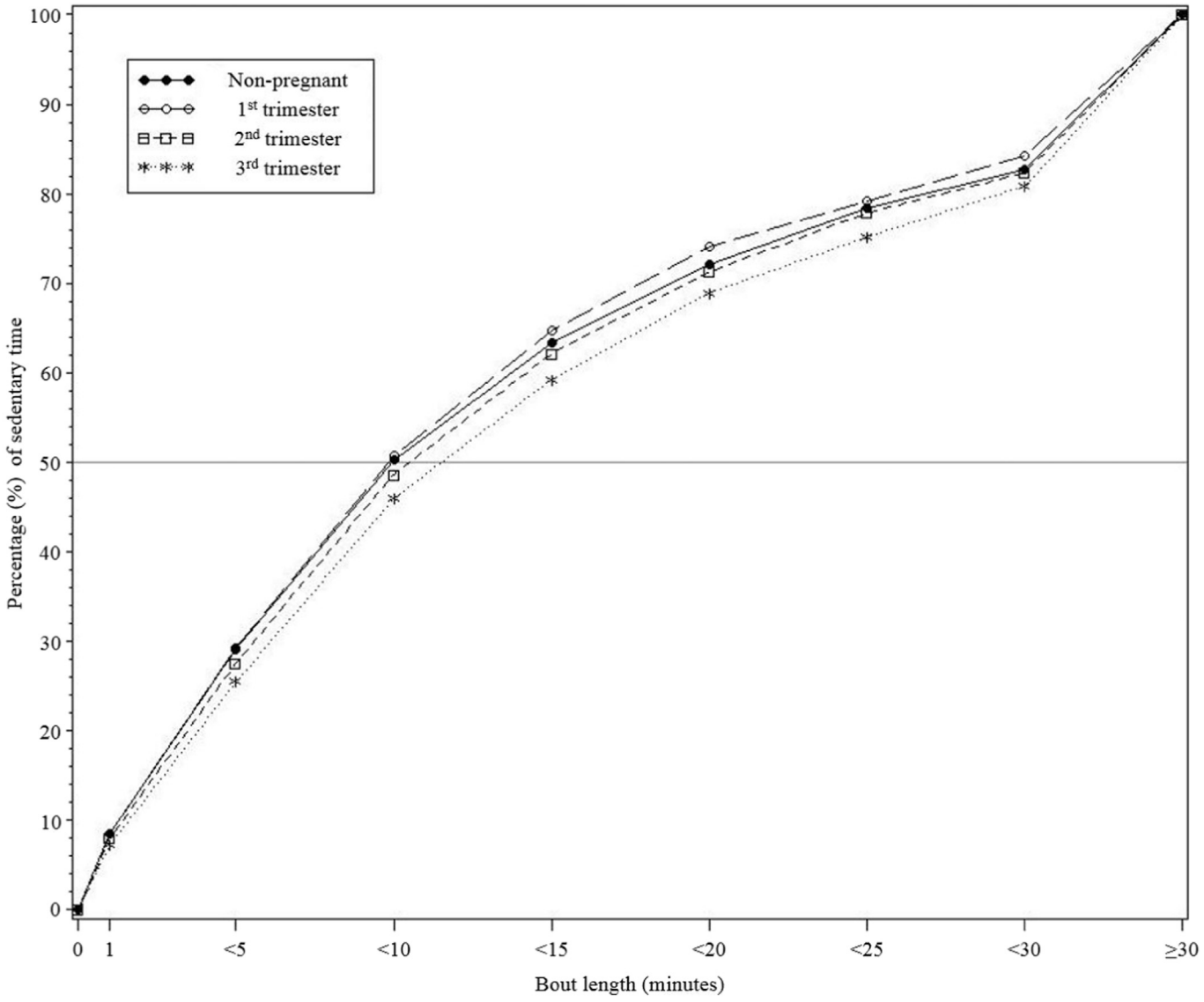

Fig. 1. Cumulative distribution of sedentary behavior accumulated in various bout lengths in non-pregnant and pregnant women by trimester.

Table 4
Sedentary bout frequency[c] within discrete bout lengths among non-pregnant women and pregnant women by trimester of pregnancy.

	Non-pregnant			Pregnant			1st Trimester			2nd Trimester			3rd Trimester		
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI	
Bout Frequency (number/d)															
1 to 4 min bouts	68.4	67.2	69.6	67.3	64.4	70.3	71.5	61.2	81.0	68.6	64.9	72.2	63.0	58.2	67.8
5 to 9 min bouts	14.6	14.4	14.8	15.3[a]	14.8	15.8	16.4	15.7	17.2	15.1	14.4	15.8	14.8[b]	14.1	15.4
10 to 14 min bouts	5.1	5.0	5.2	5.6[a]	5.2	5.9	5.8	5.3	6.3	5.5	5.4	5.9	5.5	4.8	6.2
15 to 19 min bouts	2.4	2.4	2.5	2.7[a]	2.5	2.9	2.4	1.9	3.0	2.7	2.4	2.9	2.8	2.5	3.2
20 to 24 min bouts	1.4	1.3	1.4	1.4	1.2	1.5	1.3	0.9	1.7	1.3	1.2	1.5	1.4	1.2	1.7
25 to 29 min bouts	0.8	0.7	0.9	0.9	0.8	1.0	0.9	0.7	1.1	0.8	0.6	0.9	1.0	0.8	1.2
> 30 min bouts	1.8	1.7	1.9	2.0	1.8	2.2	1.7	1.2	2.2	2.0	1.7	2.2	2.2[b]	1.8	2.6
Day-to-day variability (CV%)															
1 to 4 min bouts	5.3	5.1	5.6	5.1	4.6	5.5	5.2	4.4	6.1	4.8	4.1	5.5	5.3	4.6	5.9
5 to 9 min bouts	3.9	3.8	4.1	4.2	3.5	4.9	5.5	2.9	8.1	4.0	3.4	4.6	3.7	3.3	4.1
10 to 14 min bouts	2.4	2.3	2.5	2.5	2.2	2.8	2.9	1.8	4.0	2.5	2.2	2.7	2.4	2.0	2.7
15 to 19 min bouts	1.7	1.6	1.8	1.8	1.6	2.0	1.9	1.3	2.4	1.7	1.5	1.9	2.0	1.5	2.4
20 to 24 min bouts	1.2	1.2	1.3	1.2	1.1	1.4	1.3	0.9	1.6	1.1	1.0	1.2	1.3	1.1	1.5
25 to 29 min bouts	0.9	0.9	0.9	1.0[a]	0.9	1.1	0.9	0.8	1.1	0.9	0.7	1.0	1.2[b]	1.0	1.5
≥ 30 min bouts	1.4	1.4	1.5	1.5	1.3	1.7	1.4	0.9	1.9	1.4	1.3	1.6	1.6	1.4	1.9

[a] Statistically significant difference compared with non-pregnant women.
[b] Statistically significant linear trend among pregnant women.
[c] All estimates are adjusted for age and total wear time.

to-day variability of mean, median, or usual bout lengths between non-pregnant and pregnant women or across trimesters of pregnancy.

3.4. Bout frequency

Finally, we calculated bout frequencies within discrete bout categories (Table 4). Most sedentary bouts lasted <5 min regardless of pregnancy status. Overall, there were no statistically significant differences in sedentary bout frequency between non-pregnant and pregnant women regardless of bout length, except bouts lasting between 5–9, 10–14, and 15–19 min. Specifically, pregnant women accumulated a small but statistically significant higher number of bouts in this range. There was also a statistically significant linear trend of a fewer number of bouts between 5 and 9 min and a higher number of bouts ≥30 min across trimesters of pregnancy.

The day-to-day variability in bout frequency within discrete bouts categories ranged between 0.9% and 5.5%. There was a small but statistically significant difference in day-to-day variability between non-pregnant and pregnant women in sedentary bouts lasting 25–29 min (0.9% vs. 1%, respectively; $p = 0.04$). Among pregnant women, there was a small but statistically significant linear trend of increasing variability by trimester of pregnancy for bouts lasting between 25 and 29 min (1st trimester = 0.9%, 2nd trimester = 0.9%, 3rd trimester = 1.2; p for linear trend 0.02).

4. Discussion

This study provides the first characterization of accelerometer-determined indicators of sedentary behavior in US pregnant and non-pregnant women. We found that the minimum bout threshold applied influenced estimates of sedentary time and patterns of sedentary time accumulation across pregnancy trimesters. For example, when applying a minimum threshold of at least 15 min, sedentary time increased across pregnancy trimesters. Most of the accumulated sedentary time in non-pregnant and pregnant women was accumulated in bouts lasting <10 min. While the mean and median bout lengths were <5 min, the "usual" sedentary bout length was approximately 10 min, increasing over pregnancy trimesters. Finally, non-pregnant and pregnant women performed <2 sedentary bouts per day lasting ≥30 min, however, these accounted for nearly 20% of total accumulated sedentary time.

These results illustrates that the decisions investigators make when operationalizing sedentary behavior bouts (e.g., ≥1 min vs. ≥10 min) as the targeted exposure variable will impact estimates of sedentary time. This has important implications because the differences in sedentary behavior exposure estimates may impact the observed measures of association with pregnancy outcomes. While the underlying behavior doesn't change, the resulting estimate will vary depending on the threshold that investigators use. The minimum bout length applied also influenced patterns of accumulated total sedentary time across trimesters of pregnancy. Specifically, sedentary time was similar across pregnancy trimesters when using a minimum bout length <15 min. However, there was a statistically significant trend of increasing total accumulated sedentary time when a minimum bout length of ≥15 min was applied.

We further characterized how sedentary time was accumulated in non-pregnant and pregnant women. We found that nearly 30% of the total sedentary time was accumulated in bouts lasting <5 min. Additionally, approximately 21% of total sedentary time was accumulated in bouts lasting between 5 and 9 min, which decreased over trimesters of pregnancy. This decrease indicates more time was accumulated in longer bout lengths. Indeed, women in their first, second, and third trimester of pregnancy accumulated 13.7%, 17.8%, and 18.5% of their total sedentary time in bouts lasting at least 30 min. Moreover, the usual sedentary bout length increased over the course of pregnancy with the usual bout lasting 9, 10, and 11.1 min in the first, second, and third trimester, respectively. Potentially, this change in how sedentary time is accumulated may be associated with greater cardio-metabolic risk. For example, Healy et al. found that individuals that had few breaks (i.e. longer bouts) in sedentary time had a worse cardio-metabolic profile than individuals that had many breaks (Healy et al., 2011). Unfortunately, NHANE did not collect information on pregnancy related outcomes.

Consistent with other reports, bouts lasting <5 min were most frequent, ranging from approximately 60 bouts/d to 70 bouts/d. The number of bouts lasting ≥30 min was low in non-pregnant and pregnant women (1.8 bouts/d and 1.9 bouts/d, respectively). There was a small but statistically significant increase in the number of 30-min bouts by trimester of pregnancy. Despite the small number of bouts lasting at least 30-min, they still accounted for up to 20% of total sedentary time. Future interventions on sedentary behavior will have to determine whether it's more effective to target reducing sedentary time overall, which is largely accumulated in short bouts, or breaking up the relatively few prolonged bouts.

Few previous studies have reported characteristics of sedentary behavior using population-based samples. Previous analysis of NHANES described accelerometer-determined physical activity and sedentary behavior in US pregnant women (Evenson and Wen, 2011). Similarly, they reported that pregnant women spent 57.1% of their waking wear time in sedentary behavior using the every minute counts approach as compared to 57.3% in the current study. However, the authors did not report any other characteristic of sedentary behavior. Other studies of non-pregnant young adults have reported comparable estimates of sedentary time, patterns of sedentary accumulation, and usual sedentary bout length. In 773 young (~22 years) men and women participating in the Raine Study, women spent approximately 62.8% of their waking wear time in sedentary behavior using the every minute counts approach (McVeigh et al., 2016). Further, women accumulated 34.5% and 21.5% of the total sedentary time in bouts of at least 20 min and 30 min respectively as compared to 16.5% and 10.1% in our study. Overall the usual bout length of participants in this study was slightly higher than ours, lasting approximately 12 min as compared to 10.2 min in our study. Other studies to report accelerometer-determined characteristics of sedentary behavior were from older adult populations, generally reporting more sedentary behavior.

While this study is novel in that it is the first study to characterize several indicators of sedentary behavior in pregnant women, there are limitations worth noting. First, we had a relatively small sample of pregnant women, especially women in their first trimester of pregnancy. This could have perhaps reduced the generalizability of our estimates of sedentary behavior, particularly as relates to the first trimester. Similarly, the limited sample size did not allow us to explore differences by race/ethnicity. Another limitation was the lack of information on parity. Parity is related to physical activity levels and may also influence sedentary behavior (Dumith et al., 2012). We were unable to test interactions to determine the extent to which parity affects sedentary behavior. In addition, no available data on whether women were pregnant with multiples or had a pre-existing (or acquired during pregnancy) health condition that would influence their sedentary time. Lastly, previous research has reported measurement error when using a hip worn accelerometer to measure steps in pregnant women (Connolly et al., 2011). To the extent to which there is also measurement error in measuring sedentary behavior in pregnant women, this could impact comparisons between pregnant and non-pregnant women, and across trimesters of pregnancy. Likewise, the study monitor is unable to identify transitions from sitting to standing or distinguish between standing with little movement (i.e. light intensity activity) and sitting (i.e. sedentary behavior). This could also impact our estimates of sedentary time. However, because this limitation would have impacted both non-pregnant and pregnant women similarly, it should not have substantively impacted differences in patterns between non-pregnant and pregnant women.

In conclusion, this is the first study to characterize of accelerometer-determined indicators of sedentary behavior in a sample of pregnant and non-pregnant women. These results illustrate how estimates of

sedentary time can change based on how the investigator decides to operationalize the behavior. Future research is needed to identify if, and to what extent, the choice of sedentary behavior exposure estimate(s) used in analyses influences subsequent associations with pregnancy outcomes.

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Conflicts of interest

We have no conflicts of interest, financial or otherwise.

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