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Compliance with wrist-worn accelerometers in primiparous early postpartum women

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Abstract

Background: There are few studies that objectively assess physical activity using accelerometry in postpartum women and none that do so before 3 months postpartum. It is not known whether accelerometry can be successfully used in the early postpartum period and thus benefit studies designed to assess the health benefits and risks of early physical activity. Wear compliance may be substantially lower several weeks after childbirth, given the overwhelming nature of the early postpartum period, particularly for first time mothers. The aims of this study were to 1) describe the methods used to facilitate protocol compliance of wrist-worn accelerometry, 2) describe device usage and wear time in early postpartum primiparous women and 3) to place the compliance characteristics of early postpartum primiparous women in our study in context with that of other studies of postpartum women and standards published by large, physical activity surveillance studies.

Methods: Participants were primiparous women who were enrolled at 3rd trimester in a larger ongoing prospective cohort study, delivered vaginally, and lived in a 60 mile radius of the research site. The parent study was designed to evaluate the effects of early physical activity on pelvic floor health. Participants wore a wrist

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accelerometer (ActiGraph™ GT3XLink device) over two 7-day periods, 2−3 weeks and 5−6 weeks postpartum. We developed a protocol based on best practices to enhance compliance in this population. The Choi (2011) algorithm was used to determine wear time.

Results: Of all participants, 82.6% (166 of 201 eligible) and 70.1% (141 of 201 eligible) at 2−3 and 5−6 weeks, respectively, received and wore a functional device in the correct study time-frame for at least 7 days. Of participants that received a functional device, 94.3% (166/176) and 86.5% (141/163) wore the device for at least 7 days, with mean wear times of 1348.0 (135.8) minutes/day and 1313.5 (152) minutes/day, respectively. At 2−3 weeks, 96.1% and 90.4% met the NHANES and Whitehall II Study wear standards, respectively, while at 5−6 weeks, 93.9% and 84.1% did so.

Conclusion: Despite challenges in conducting physical activity research in postpartum women, adherence to wrist-worn accelerometry is high with this protocol.

Keyword: Public health

1. Introduction

Waist-worn accelerometry is highly regarded as a means for objectively assessing physical activity in populations. Compliance and total wear time with waist-worn accelerometry can be low, likely due to the undesirability of wearing the device on a belt, removal of the device during sleep and replacement during waking hours, and inability to wear the device in the water [1]. Poor protocol compliance leads to lower wear time and ultimately [1], less accurate estimates of physical activity and inactivity. Wrist-worn accelerometry is increasing in popularity, given various advantages: the devices are light and inconspicuous on the wrist, and can easily be worn all day and while sleeping. Therefore, wrist worn devices may be more advantageous for use in populations who may have difficulties complying with accelerometer wear on the waist. While step output differs between wrist- and waist-worn accelerometers worn during daily life, both have good to high correlations in adults [2, 3, 4]. A recent study confirmed this in postpartum women [5]. Wrist-worn accelerometry may overestimate overall energy expenditure when compared to waist-worn accelerometry due to the extra arm movement that is collected. Despite this potential disadvantage, more researchers are using wrist-worn devices due to the higher compliance rates [6].

There are few studies assessing objectively measured physical activity in postpartum women; with the exception of two recent studies [10, 22], all use accelerometers placed on the hip to measure physical activity and all request women wear the device for 7 days [1, 2, 3, 4, 5, 7, 8, 9, 11]. Compliance with wear varied widely. Between 50% and 95% of women wore or returned the accelerometer [1, 2, 3, 4, 5, 8, 10, 11].

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When compliance was further defined as data collection for at least 3 or 4 days (with some requiring at least one weekend day) for a least 6−10 hours per day, 48 % to 86% were considered compliant with this wear standard. From these studies, it is unclear whether compliance is greater for postpartum women wearing a wrist accelerometer [1, 2, 3, 4, 5, 8, 10, 11]. In a single study assessing wrist accelerometer compliance, 30 of 100 participants wore a wrist accelerometer at 3 months postpartum, but it is not stated whether all 100 had the opportunity to wear one [5].

The current studies noted above that use accelerometry to measure physical activity in postpartum women all enrolled either multiparous women or a combination of primiparous and multiparous women (that is, none were restricted to women who gave birth to their first child). In addition, the earliest time point activity was assessed was 3 months postpartum (range 3 months−12 months).

Our parent study, the Motherhood And Pelvic Health study is designed to assess whether early postpartum activity (during the first 6 weeks postpartum) impacts later pelvic floor health in primiparous women [12]. This population differs from multiparous women between 3 months and 1 year postpartum in several key ways. Sleep disturbance is the greatest during the first month postpartum and specifically affects first-time mothers more than mothers who have already delivered at least one child [13]. Sleep is erratic, and thus the difference between daytime and nighttime accelerometry tracings is less clear. Early postpartum women also have difficulty remembering to complete tasks after a delay has happened and if there are no reminders prompting them to complete the task [14].

To understand the effect of early postpartum physical activity on health outcomes of interest, it is important to maximize wear time, particularly since women's activity patterns are irregular and dictated by caring for a new infant, which requires a 24-hour monitoring cycle. Current guidelines for return to physical activity after childbirth are non-specific, and objective data are needed to develop future evidence-based physical activity recommendations for early postpartum women [15, 16].

Thus, the aims of this ancillary prospective cohort study were to 1) to describe the methods used to facilitate protocol compliance of wrist-worn accelerometry and 2) to describe device usage and wear time in early postpartum women 3) to place the compliance characteristics of early postpartum primiparous women in our study in context with other studies of postpartum women and standards published by large, physical activity surveillance studies.

2. Methods

All data collection and study procedures were approved by the University of Utah Institutional Review Board, and each participant provided written informed

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consent. Participants were nulliparous women ages 18 and older and were English- or Spanish-speaking. Women were recruited and enrolled at prenatal visits at one of seven university and community health clinics during the third trimester of pregnancy, without health problems, able to ambulate without assistance, without connective tissue disorders or prior surgery for pelvic floor disorders and who lived within 60 miles of the primary research site. Women who delivered by cesarean and/or before 37 weeks gestation were subsequently excluded while those that delivered vaginally continued in the study and will ultimately be followed for one year postpartum. Complete methods of the parent study are described elsewhere [12].

Demographic data were collected by questionnaire during the 3rd trimester of pregnancy at the time of enrollment (Table 1). The two time points for accelerometry data collection in the early postpartum period were 2−3 weeks postpartum (T1 = operationalized as 12−25 days postpartum) and 5−6 weeks postpartum (T2 = operationalized as 33−46 days postpartum). These time points were chosen to meet the goals of the parent study. Eligible women for this study were those enrolled during the first

Table 1. Participant characteristics at 3rd trimester.

Characteristic	Eligible women (%) (Total N = 201)
Age, years[a]	28 (5.1)
BMI[a]	26.17 (4.5)
Ethnicity	
Hispanic or Latino	45 (22.4%)
Not Hispanic or Latino	149 (74%)
Did not respond	7 (3.5%)
Race[b]	
Caucasian/white	161 (80.1%)
Other	40 (19.9%)
Education completed	
High school or less	28 (13.9%)
Some college/completed college	112 (55.7%)
Graduate/professional degree	57 (28.4%)
Did not respond	4 (2%)
Work status[c]	
Working part time (<30 hrs/wk)	18 (9%)
Working full time (>30 hrs/wk)	122 (60.7%)
Other	51 (25.3%)
Did not respond	10 (4.9%)

[a] Mean ± SD.

[b] Race: Other category includes: American Indian/Alaskan Native, Asian, Black/African American, Native Hawaiian/Pacific Islander, Do not wish to identify, and those that did not respond.

[c] Work status: Other category includes: unemployed, disabled/on sick leave, Homemaker, part time student, full time student, retired, and other.

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full year of the Motherhood And Pelvic Health parent study who delivered vaginally by 09/10/2016 (Fig. 1).

The following steps describe our protocol that was developed for this study. Study staff used a standardized protocol to distribute accelerometers and standardized instructions to maximize wear compliance. Study staff contacted participants by email, phone call, or text message (depending on the participant's preference) just prior to the T1 and T2 windows to determine the best schedule for delivering and wearing the accelerometer within the allowable window.

Study staff personally distributed an accelerometer to a woman's home (or to an alternate location, if requested) prior to each time point and verbally instructed her to wear a wrist-worn GT9X LINK tri-axial accelerometer on the non-dominant wrist (Actigraph™, Inc., Pensacola, FL) for 24 hours/day for 7 consecutive days, beginning at bedtime the day she received it [17]. At accelerometry delivery at T1, in addition to detailed verbal instructions, the study staff provided written instructions and answered questions. If the participant was not home, the

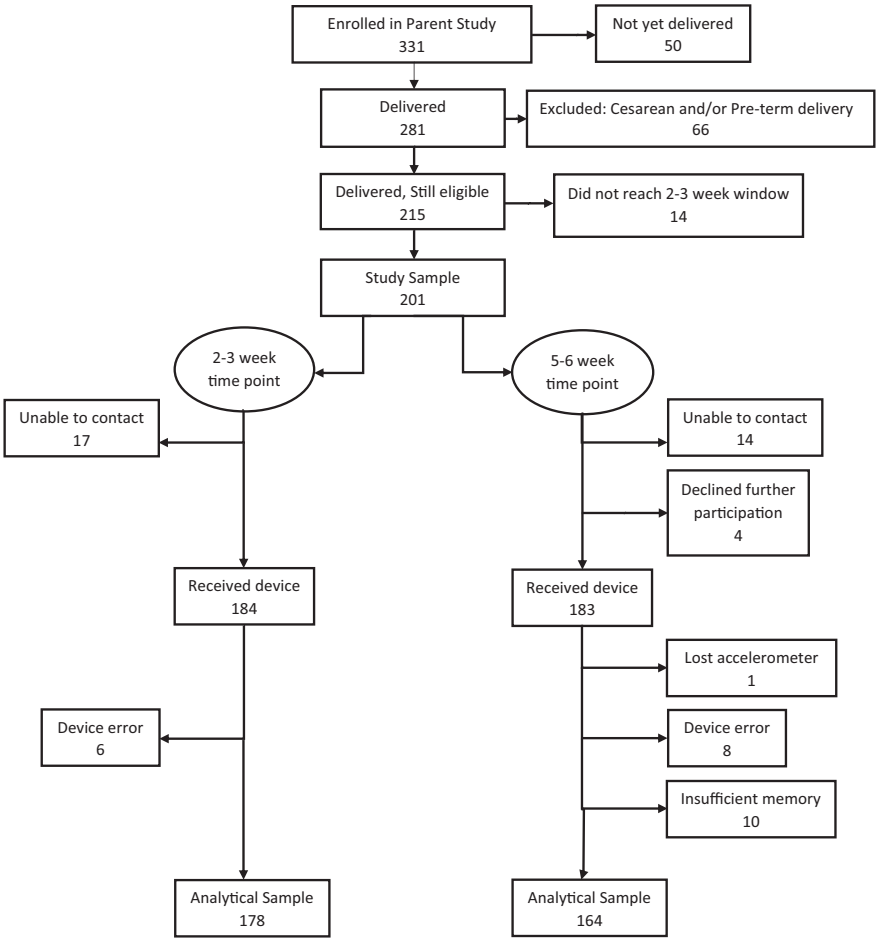

Fig. 1. Participant recruitment and retention.

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accelerometer and instruction sheet were left in a predetermined location, often in a mailbox or with a relative or spouse. Spanish-speaking participants were contacted by Spanish speaking staff, received a translated instruction sheet. In addition, for most cases, Spanish-speaking staff delivered and retrieved their accelerometers.

Study staff contacted each woman, usually by text message, one day after accelerometer distribution to ensure the woman was wearing the device and to answer any further questions about the accelerometer. Staff also contacted the woman 8 days later to ask whether she was able to wear the accelerometer for at least 4 of the 7 requested days. If so, she was instructed to remove the accelerometer and informed that someone would contact her in 7−10 days to schedule the second (T2) accelerometer distribution. If she had not worn the accelerometer for at least 4 days, and if additional days were still in the allowable time window, she was asked to continue wearing it until she had at least 4 days of wear. Study staff dropped off the second accelerometer at 5−6 weeks postpartum, again verbally explained the instructions, and picked up the first accelerometer and returned it to the Physical Activity Research Laboratory for data download. If there was not a convenient time to pick up the first accelerometer during delivery of the second, then the woman returned both accelerometers at the time of her scheduled 6−10-week postpartum Motherhood And Pelvic Health study visit [12]. Participants received a $20 gift card at each time point for wearing the accelerometer.

The ActiGraph™ GT9X Link accelerometer used in this study contains the same accelerometer machine as the previous GT3X accelerometer and has shown high levels of reliability and validity at the hip and wrist locations in comparative research [3, 18]. This accelerometer has become widely popular and has been used for large surveillance research, such as the National Health and Nutrition Survey (NHANES) [19]. ActiLife 6.13.0 software was used to initialize the devices, download data, and determine wear time using the Choi (2011) algorithm using the vector magnitude score [20]. Initialization parameters were standardized using the ActiLife template option and followed the 2011 NHANES physical activity measurement manual [19]. Devices were initialized for a start time of 12:00 am, sample rate of 80 Hz, disabled wireless mode, enabled idle sleep mode, indicated there was no data collection stop date, and that device display had current 24-hour time so the participants could use the accelerometer as a functional watch. Initialization start date was for the day following scheduled distribution date. The initialized device was placed into an ActiGraph™ watch band and placed in an envelope with an instruction sheet. All data were stored in a secure university cloud platform.

Accelerometry data were visually inspected to describe the number of weekdays and weekend days with wear time. Mean daily wear time was determined using the Choi (2011) algorithm for wrist worn devices [20].

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In order for data to be compliant with the main study, data collected outside of the 2−3 and 5−6 week time windows was not considered valid. Therefore, if a participant wore the accelerometer entirely outside of the two allotted time windows, 12−25 days postpartum and 33−46 days postpartum, wear time was recorded as 0. Data sets with consecutive and nonconsecutive days of wear were included in analyses. Wear time that exceeded 7 days but that was still in the time window was also noted.

We used Microsoft Excel (2016) to describe the total number of days, and the subdivisions of weekdays and weekend days with any wear time for each participant at each time point. Means and standard deviations of total days, weekdays, and weekend days with any wear time, and for minutes of wear time were computed separately for the two data collection periods. We assessed differences in demographic characteristics between three groups of participants: those who completed T1 and T2 with $\geq$7 days of wear for each; those who completed T1 and T2 with $<$7 days of wear for at least one time period; and those who only wore the accelerometer at only one or neither time point. We compared the groups using one-way ANOVA for continuous and Pearson chi-square tests for categorical variables. We used the Exact McNemar's test to compare 7-day compliance between T1 and T2.

A significant P-value was set at 0.05. Analysis was computed using IBM SPSS Statistics Package Version 25.0 (Armonk, NY, USA).

We placed our wear characteristics at 2−3 weeks and 5−6 weeks in the context of the standards of two large surveillance studies: 1) 2003−2006 NHANES standard − at least 10 hours of wear time per day on 3+ weekdays and 1+ weekend days 2) Whitehall II Study standard − at least 16 hours of wear time per day on 2+ weekdays and 2 weekend days [19, 21, 22, 23].

3. Results

The protocol described in the methods section was developed from literature of accelerometry best practices [17, 19, 23] and the early postpartum population [1, 7, 13, 14].

The study sample consisted of 201 participants who delivered vaginally by 09/10/2016. Of 201 women eligible for this study, at T1, (we were not able to contact 8.5% (17) women to distribute the device. Of those 184 who received an accelerometer here were 2.9% (6) device errors, leaving 178 women in the final analytic sample for T1. Of the 201 eligible at T2, we were not able to contact 6.9% (14) to distribute the device and 2.0% (4) declined further participation, thus 183 received an accelerometer. Of the 183 who received an accelerometer, there were 3.9% (8) device errors, 0.5% (1) that lost the accelerometer, and 4.9% (10) whose devices

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prematurely stopped collecting data due to insufficient memory, leaving 164 women in the final analytic sample for T2.

As noted, we were not able to completely assess device use in ten women whose devices prematurely stopped collecting data. This occurred due to an effort to improve the efficiency of our accelerometer delivery and pick-up procedures. We attempted initially to collect T1 and T2 data on one accelerometer that the participant retained for the period between 2−3 weeks and 5−6 weeks. Study staff contacted these participants about when to take off the device and when to put it back on. As we had projected, the battery life was sufficient, but the memory storage was insufficient for this approach and the accelerometers automatically stopped collecting data once maximal memory was attained. This occurred before complete data collection. Therefore for this ancillary study, we did not think that this insufficient memory error would accurately reflect wear time patterns for these participants. Thus, we removed these 10 women from our T2 analytical sample. Device errors at both time points included 1 device failure, 11 firmware/software incapability errors, and 2 user errors.

Of the 201 women, 2% (4) had no accelerometry data at both time-points because of inability to contact or device error, 91% (182) wore an accelerometer that contained data for 1 or both time points, and 7% (14) had no valid accelerometry data for either time point (for example, they didn't wear the accelerometer at one time point and then wore it outside the window or the device had insufficient memory the other time point). The median wear time for both time periods combined was 1357.3 minutes/day (Interquartile Range 1187.7, 1526.9).

At 2−3 weeks postpartum (T1), of the 178 women who received a functional device, 93.3% (166) wore it as requested for 7 days with a mean wear time of 1348.0(SD 135.8) minutes/day (Table 2). Two wore the device outside of the allowable time window and therefore were assigned 0 days and 0 minutes of wear time. There were 2.8% (5) who had no wear time on any weekend day. Seventeen women wore the device continuously for 7 days (mean wear time of 1440 minutes per day, each day). Over half (91) of women wore the device for longer than 7 days (1.6 (0.93) additional days beyond 7; range = 1−5 days).

At 5−6 weeks postpartum (T2) 86.5% (141/164) women wore the device for 7 days with a mean wear time of (1313.5 (152.0) minutes/day (Table 2). One did not wear the device during the allowable time window. There were 2.4% (4) who had weekend wear time only on Saturday with a mean of 484.6 (685.4) minutes and 3 (1.8 %) had no wear time on either weekend days (Table 2). Twenty-two women had a mean wear time of 1440 minutes per day. Approximately 42.6% (70) wore the device for longer than 7 days (1.7 (0.91) additional days beyond 7; range = 1−5) for a mean of 1011.6 (331) minutes per day. At each time point, fewer than 1% of women did not wear the device once it was received or wore the device solely outside the allowable time window.

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Table 2. Number and Percentage of women with total days, weekdays, and weekend days of wear time at 2−3 weeks postpartum (T1) and 5−6 weeks postpartum (T2).[a]

	T1: Percentage (N) (Total = 178)	T1: Mean (SD) Wear Time, minutes/day	T2: Percentage (N) (Total = 164)	T2: Mean (SD) Wear Time, minutes/day
Total 7 days	93.3% (166)	1348.0 (135.8)	86.5% (141)	1313.5 (152)
5 weekdays	93.3% (166)	1338.8 (136.1)	86.5% (141)	1313.2 (149.7)
4 weekdays	3.4% (6)	1089.6 (632.3)	9.8% (16)	890.6 (589.3)
3 weekdays	0% (0)	0	3.7% (6)	766.6 (635.3)
2 weekdays	1.7% (3)	775.0 (416.8)	0% (0)	0
1 weekday	0.6% (1)	51.4 (115.0)	0% (0)	0
No weekdays	0.1% (2)	0	0.006% (1)	0
Both weekend days	97.2% (173)	1372.6 (63.6)	95.7% (157)	1307.7 (88.3)
Saturday only	0% (0)	0	2.4% (4)	484.6 (685.4)
Sunday only	0% (0)	0	0% (0)	0
No weekend days	2.8% (5)	0	1.8% (3)	0

[a] 24 hours = 1440 minutes.

Of women that received a functioning accelerometer, there was no statistically significant difference between T1 and T2 in the proportion who wore it for at least 7 days (87.6% at T1 and 81.4% at T2, $p = 0.13$). There were no statistically significant differences in BMI, age, ethnicity, education completed, or work status at 3rd trimester between women who completed T1 and T2 with $\geq$7 days of wear; those who completed T1 and/or T2 with <7 days of wear; and those who only wore the accelerometer at one or neither time point (Table 3).

A high proportion of participants who received a functional accelerometer met the valid wear time criteria specified in two large surveillance studies in non-pregnant or postpartum populations. At 2−3 weeks, 96.1% (171/178) met the NHANES wear standards and 90.4% (161/178) met the Whitehall II Study wear standards. At 5−6 weeks, 93.9% (154/164) met the NHANES wear standards and 84.1% (138/164) met the Whitehall II Study wear standards (Table 4). When all eligible women at each time point are considered, including those that we were unable to contact or in whom there were device errors, 85.1% (171/201) and 80.1% (161/201), respectively, met the criteria for NHANES and Whitehall II standards at 2−3 weeks, while 76.6%% (154/201) and 68.6% (138/201) did so at 5−6 weeks.

4. Discussion

To our knowledge, this is the first study assessing feasibility of and adherence with accelerometry in a postpartum population during the first six weeks after delivery

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Table 3. Comparison of adherence groups.

	T1 and T2 with ≥7 days of wear N = 129	T1 and T2 with <7 days of wear N = 32	Wore at one timepoint or none N = 40	P-value
Age[a]	28.3 (4.99)	28.3 (5.51)	27.1 (5.2)	0.417
BMI[a]	26.1 (4.5)	26.8 (5.16)	25.6 (4.6)	0.566
Ethnicity[b]				0.596
Hispanic or Latina, N = 43	26/43	6/43	11/43	
Not Hispanic or Latina, N = 151	100/151	23/151	28/151	
Education completed[c]				0.114
High school or less, N = 37	19/37	7/37	11/37	
Some college/completed college, N = 103	74/103	11/103	18/103	
Graduate/professional degree, N = 57	36/57	12/57	9/57	
Work status at 3rd trimester				0.799
Working part time (<30 h s/wk), N = 22	15/22	4/22	3/22	
Working full time (>30 hrs/wk), N = 123	79/123	20/123	24/123	
Other[d], N = 46	30/46	5/46	11/46	

[a] Mean ± SD Denominators do not add up to the total study sample of 201 due to missing data. Descriptions of missing data are listed below.

[b] For ethnicity, N = 7 did not respond from the total sample and were not included in the analysis.

[c] For education completion, N = 4 did not respond from the total sample and were not included in the analysis.

[d] Work status at 3rd trimester: Other category includes: unemployed, disabled/on sick leave, Homemaker, part time student, full time student, retired, and other. In addition, N = 10 did not respond for work status in the total sample and were not included in the analysis.

and the first to study this in primiparous women. Our results show that wrist accelerometry is acceptable to this population and adherence to the protocol is high. To achieve this, we implemented best practices for accelerometry into our protocol [24]. The best practices we found for an accelerometry protocol in the early postpartum population are described here in detail. First, we prioritized personal distribution of devices paired with multiple points of contact via text, phone, or email. Verbal and written instructions were provided in both English and Spanish, and modest compensation after device retrieval. We sent two reminders to women during each week of wear. While others have used written logs to promote accelerometry compliance, we were concerned about the burden any additional study requirements would have on this early postpartum population and did not include logs in our protocol [24].

Study staff usually retrieved the devices, or the participant brought the device with her to her postpartum visit and study staff retrieved it there. Our participants, first

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Table 4. Adherence rates based on various criteria.

Adherence criterion	2–3 weeks	5–6 weeks
Able to contact participant and deliver device	91.5% (184/201)	91.1% (183/201)
Device received and worn with no device error	96.7% (178/184)	90% (164/183)
Device received, no device error, worn in correct study timeframe	95.7% (176/184)	89% (163/183)
Device received, no device error, worn in correct study timeframe for ≥7 days	94.3% (166/176)	86.5% (141/163)
Of all participants, device received, no device error, worn in correct study timeframe for ≥7 days	82.6% (166/201)	70.1% (141/201)
Device received, no device error, met wear criteria for NHANES	96.1% (171/178)	93.9% (154/164)
Device received, no device error, met wear criteria for Whitehall II	90.4% (161/178)	84.1% (138/164)
Of all participants, no device error, met wear criteria for NHANES	85.1% (171/201)	76.6% (154/201)
Of all participants, no device error, met wear criteria for Whitehall II	80.1% (161/201)	68.6% (138/201)

time mothers, were sensitive about door bells ringing, phone notification sounds, and other noises at these early time points and appreciated our willingness to tailor our protocol to these concerns when contacting them and distributing accelerometers to their homes. Text messaging was typically the preferred method of contact because it was least intrusive. Women also seemed to value having the opportunity to ask questions in person about the accelerometer and wearing instructions since most were not familiar with the device and needed reminders about the exact instructions. The written instructions included phone numbers for both English and Spanish-speaking study staff so that they could contact us if they had questions or concerns. In some populations, this protocol may seem to include a burdensome amount of communication and reminders, but in early postpartum women, this level of contact may be required to achieve optimal wear time compliance. While our study did not compare the effect of different protocols on adherence, the result of these efforts demonstrates generally high patterns of wear.

However, we were not able to contact participants in order to deliver the device in 8.5% and 6.9% of instances at 2–3 weeks and 5–6 weeks postpartum, respectively. This may be a unique issue with postpartum women, as some of these participants stayed with relatives or friends or avoided telephone use during the early postpartum period. Depending on various criteria used to describe adherence, rates varied from 68.6% to 96.7% (Table 4). From a device usage perspective, adherence was very high: over 85% of women that received a functional accelerometer provided 7 days of accelerometry data and for greater than 20 hours of wear per day at both

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time points and over 95% wore it on both weekend days. From a research study perspective, it is helpful to be able to predict the proportion of all participants that ultimately yield analyzable accelerometry data. For analyzable accelerometry data adherence is lower but still very good, with 70%−83% of all participants wearing a functional device in the correct study time frame for at least 7 days. Given the high proportion that meet wear criteria for two large population-based studies (which are also consistent with criteria in much of the published literature), we are reasonably confident that wrist accelerometry will yield representative physical activity data in this early postpartum population.

A small number of other studies have used accelerometry to assess physical activity in postpartum women [1, 2, 3, 4, 5, 7, 8, 9, 10, 11]. As noted previously, populations in these studies were either partly or entirely multiparous, and data collection occurred between 3 months and 1 year postpartum. With the exception of two studies in postpartum women [5, 10], the accelerometers were worn on the hip. The definitions for compliance were either 3 or 4 days, generally including one weekend day, with wear time between 6 and 10 hours. In one study, women at 14 weeks postpartum wore the SenseWear^{TM} Pro [3] armband on the right arm for 24 hours/day, the final analysis ultimately included women who wore the armband for $\geq$19.2 hours/day for $\geq$ any 2 days [10]. The authors noted that while previous literature recommends 3−5 days of valid data to assess habitual physical activity, using those standards would have decreased their sample size [10]. It is not clear whether this lower adherence is related to the specific device or to additional participant contact or incentives to facilitate protocol compliance, which were not mentioned in this paper.

Of the literature to date, the PIN3 Study had methods most similar to ours, in that women received verbal and written instructions for wear by study staff during a personal home visit, were given a phone number to call if they had any questions, and received monetary compensation upon completion [1]. However, the accelerometer was waist-worn accelerometer, women were instructed to remove the accelerometer when sleeping, bathing, or swimming, data were collected at later time points (3 and 12 months) postpartum, and participants returned devices by mail with provided postage paid envelopes. In this study, at 3 months postpartum, 57% of participants wore the device and 48% wore it and met criteria for compliance. Given similarly labor-intensive study protocols, it seems reasonable to attribute the higher compliance rates seen in our study partly due to the wrist location, rather than waist location. Increasing wear time can reduce the need for data imputation of missing values, further increasing the importance of protocols for maximizing accelerometer wear time [1, 17, 21]. We anticipated longer wear times in the Motherhood And Pelvic Health study compared to those in PIN3 due to differences in devices and collection methods. The PIN3 study designated waking hours for women to be from 5 am to midnight and therefore performed data imputation for the missing data values during

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this timeframe to create a 19-hour day for physical activity analysis [1]. The overall mean wear time was 12.2 hours/day at 3 months postpartum. Eighty percent of women who were enrolled and completed accelerometry at 3 months postpartum achieved the NHANES standard [1]. In the Motherhood And Pelvic Health study, greater than 90% of women whom received a functioning device met the NHANES standard at both time points, again, likely highlighting advantages of wrist-worn accelerometry. However, three other studies using hip-worn accelerometers in postpartum women described rates of compliance or valid data of 86% at 14 weeks postpartum and 78% at 6 months postpartum, and in the third study, 69% had valid data at both 6 month and 10 month timepoints; notably, all three were randomized trials of clinical interventions for weight loss and may represent particularly motivated populations [7, 8, 11].

In terms of comparisons between our data and that of non-postpartum populations, in the 2003−2004 NHANES population, 60% of healthy women aged 20−39 years, a similar population in terms of age to women in our study, met the wear time standard of ≥10 hours on 4 days while wearing a waist-worn device [22]. More recently, the 2011−2012 NHANES utilized wrist-worn devices and showed among participants who had at least 1 acceptable wear day, there was a median wear time of 22 hours/day and 70−80% of total participants provided at least 6 days with 18 hours/day or more of wear time [17]. Decision rules for optimal wear time to reflect habitual physical activity using wrist worn devices have not yet been established. The Whitehall II study collected accelerometry data from healthy men and women aged 60−83 years between 2012 and 2013 using the GeneActiv tri-axial wrist-worn accelerometer. The wear time standard was defined as ≥16 hours of wear on 2+ weekdays and 2 weekend days [23]. In this population, very different than women in the Motherhood And Pelvic Health study, 94.4% of those that received a device met the valid wear standard [23]. In comparison, 90.4% of our population met this standard, over a 7-day period, at 2−3 weeks and 84.1% met the standard at 5−6 weeks postpartum.

This study has limitations. The study's participants were limited to healthy, primiparous postpartum women who delivered vaginally and lived within 60 miles of a large mountain west city [12]. Therefore, these results cannot be generalized to other populations. While we found no significant differences in demographic characteristics between women who wore the accelerometer at both time points for 7 days, those that wore it for less than 7 days at one or both time points, and those that wore it at one time point or not at all, there may be other differences that we did not study. Personal distribution of accelerometers is not realistic in large population surveillance studies but was attainable for a smaller sample with a large team of student volunteers. The Motherhood And Pelvic Health study recruited participants during the 3rd trimester of pregnancy and has a focus on pelvic floor health, and various objective measures are assessed in addition to accelerometry measures [12]. The study did not seek to recruit women specifically interested in physical

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activity. These recruitment and study details make it likely that women with a wide range of physical activity levels and interests are included in the study.

Before embarking on this study, we conducted a pilot study to assess accelerometry battery and memory lives in real use. Based on this, we initially assigned each woman one accelerometer for data collection for both time-points. We found that the battery life was sufficient, but the memory was not, resulting in no usable data for the second time-point for ten women. This resulted in the change to our manual of operations and for all future visits we required that new devices be delivered for each time-point. It may have been burdensome for the participants to receive a new device at each time point and this may have resulted in different wear times at 5–6 weeks than had participants used one device for each of the two distinct time periods.

Additional efforts may be needed to obtain addresses or contact information for participants who are temporarily relocated in the immediate postpartum, to further reduce the number of participants with no data due to inability to contact. However, most women wore the accelerometer for at least one of the two time-points.

5. Conclusion

To our knowledge, this is the first study to assess accelerometry usage in women in the early postpartum period. The results are encouraging for researchers who wish to study the effect of physical activity interventions during this early period. Most participants complied with the study protocol and demonstrated high mean wear time values over the 7-day collection period at both time periods. In summary, in an early postpartum population in which women have many competing new challenges, the wear statistics for wrist accelerometry, used in the context of a protocol designed to enhance compliance, compares favorably to those of population-based studies and are generally better than studies of postpartum women using hip-worn devices.

Declarations

Author contribution statement

Ali E. Wolpern, Janet M. Shaw: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Kyle J. Sherwin, Whitney D. Moss: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ingrid E. Nygaard, Marlene J. Egger, Timothy A. Brusseau: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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