Using Activity Trackers to Quantify Postpartum Ambulation

A Prospective Observational Study of Ambulation after Regional Anesthesia and Analgesia Interventions

Julia Ma, B.Sc., M.P.H., Rachel Martin, M.D., F.R.C.P.C., Bokman Chan, M.D., F.R.C.P.C., Michael Gofeld, M.D., F.I.P.P., D.E.A.A., Michael P. Geary, M.B., B.Ch., B.A.O., F.R.C.O.G., F.R.C.P.I., M.D., D.C.H., John G. Laffey, M.D., M.A., F.C.A.I., Faraj W. Abdallah, M.D.

ABSTRACT

Background: Early postoperative ambulation is associated with enhanced functional recovery, particularly in the postpartum population, but ambulation questionnaires are limited by recall bias. This observational study aims to objectively quantify ambulation after neuraxial anesthesia and analgesia for cesarean delivery and vaginal delivery, respectively, by using activity tracker technology. The hypothesis was that vaginal delivery is associated with greater ambulation during the first 24 h postdelivery, compared to cesarean delivery.

Methods: Parturients having first/second cesarean delivery under spinal anesthesia or first/second vaginal delivery under epidural analgesia between July 2015 and December 2016 were recruited. Patients with significant comorbidities or postpartum complications were excluded, and participants received standard multimodal analgesia. Mothers were fitted with wrist-worn activity trackers immediately postdelivery, and the trackers were recollected 24 h later. Rest and dynamic postpartum pain scores at 2, 6, 12, 18, and 24 h and quality of recovery (QoR-15) at 12 and 24 h were assessed.

Results: The study analyzed 173 patients (cesarean delivery: 76; vaginal delivery: 97). Vaginal delivery was associated with greater postpartum ambulation (44%) compared to cesarean delivery, with means ± SD of 1,205 ± 422 and 835 ± 381 steps, respectively, and mean difference (95% CI) of 370 steps (250, 490; $P < 0.0001$). Although both groups had similar pain scores and opioid consumption (less than 1.0 mg of morphine), vaginal delivery was associated with superior QoR-15 scores, with 9.2 (0.6, 17.8; $P = 0.02$) and 8.2 (0.1, 16.3; $P = 0.045$) differences at 12 and 24 h, respectively.

Conclusions: This study objectively demonstrates that vaginal delivery is associated with greater early ambulation and functional recovery compared to cesarean delivery. It also establishes the feasibility of using activity trackers to evaluate early postoperative ambulation after neuraxial anesthesia and analgesia. **(Anesthesiology 2018; 128:598-608)**

MODERN perioperative care advocates clinical pathways that expedite regain of function and/or achieving functional independence after surgical and anesthetic interventions, with commensurate emphasis placed on functional recovery outcomes.[1–5] Early postoperative ambulation is an integral component of enhanced functional recovery among surgical patients.[6–8] It is associated with improvements in numerous perioperative outcomes; enhanced pain relief, prevention of deep vein thrombosis, shorter hospital stay, faster recovery, and earlier return to normal activity have been demonstrated in various surgical populations.[8–10] In contrast, delayed ambulation is linked to worse outcomes and increased opioid analgesia requirements.[8–12] Similar findings have been observed among obstetric and gynecologic patients undergoing abdominal procedures,[12–15] and additional benefits, such as enhancing breastfeeding, facilitating newborn care,[16] and reducing the risk of thromboembolism, a major cause of maternal mortality and morbidity,[17] have also been reported among parturients. Importantly,

What We Already Know about This Topic

- Early postoperative ambulation is of benefit to patients and potentially modifiable; however, evidence regarding the ideal approach for evaluating early postoperative ambulation is lacking

What This Article Tells Us That Is New

- This study objectively demonstrates that vaginal delivery is associated with greater early ambulation and functional recovery compared to cesarean delivery
- It also establishes the feasibility of using activity trackers to evaluate early postoperative ambulation after neuraxial anesthesia and analgesia

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ambulation in the perioperative period is a modifiable factor that, with sufficient communication and encouragement, can significantly enhance recovery and promote health-seeking behaviors among surgical parturients.[10] However, evidence regarding the ideal approach for evaluating early postoperative ambulation is lacking,[14] with most tools used being subject to recall bias,[18] thus underscoring the importance of objective real-time quantification of ambulation.

Enhanced functional recovery policies emphasizing early ambulation after cesarean delivery have been implemented in several institutions worldwide,[9,13,19] including ours (St. Michael's Hospital [SMH], University of Toronto, Toronto, Ontario, Canada). In this study, we aimed to evaluate the degree of ambulation in parturients after cesarean delivery and to compare it to those having normal vaginal delivery. To objectively quantify ambulation, we used wearable activity trackers (fitness bracelets). Researchers are just beginning to explore the potential role of this novel technology in perioperative care, with nascent applications in assessing the set medium-to-long–term activity goals and lifestyle changes over days[20] to months[21] after coronary artery bypass graft[20] and bariatric surgery,[21] respectively. However, its role in evaluating immediate (day 1) postoperative or postpartum ambulation has not yet been explored.

We aimed to demonstrate the feasibility of using activity trackers to quantify ambulation after regional anesthesia and analgesia interventions. Specifically, this prospective observational study sought to show that vaginal delivery under epidural analgesia is associated with more activity in the immediate postpartum period compared to cesarean delivery under spinal anesthesia, in the setting of effective multimodal analgesia. We hypothesized that vaginal-delivery parturients would have greater ambulation, as measured by the number of steps using activity trackers, during the first 24 h after delivery, compared to their cesarean-delivery counterparts. We also assessed postoperative pain control, as measured by visual analog pain severity scores and analgesic consumption, as well as quality of recovery (QoR) as measured by the QoR-15 tool.[22]

Materials and Methods

The authors adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting observational studies[23] in preparing the analysis plan and writing this manuscript. This stand-alone observational study was not part of any other project; it was approved by the Research Ethics Board and conducted at SMH, a tertiary center in Toronto, Canada, fully affiliated with the University of Toronto, between July 2015 and December 2016.

Early Ambulation Policy

The prospective cohort study commenced in July 2015, 3 months after the introduction of the new postcesarean ambulation policy at SMH in April 2015, and concluded in December 2016. The 3 months were meant to give members of the multidisciplinary care team the opportunity to familiarize themselves with the changes to patient care and to allow the integration of the new policy into the care standard. In the absence of contraindications, the policy permits ambulation as soon as spinal anesthesia wears off, as confirmed by a Bromage (scores of motor block: 0 = normal, 1 to 3 = reduced motor power) score = 0. It calls for removal of the Foley catheter 6 to 8 h after cesarean delivery, sets early ambulation as a goal, and provides frequent reminders and encouragement by nurses providing care to achieve this goal. Having a shower at 24 h, or as early as possible, is also set as a benchmark to enhance the general wellbeing and facilitate earlier discharge. The policy also modified the suturing technique care standard into subcutaneous absorbable sutures to reduce the postsurgical wound maintenance requirements.

Study Population

We aimed to evaluate the ambulation of parturients during the first 24 h postdelivery for cesarean delivery in comparison to vaginal delivery. All female patients who had a vaginal delivery or cesarean delivery at SMH between July 2015 and December 2016 were considered. To minimize confounding in this observational study, we planned to minimize the role of factors that may favor one mode of delivery (*e.g.*, cesarean delivery) over the other and at the same time influence the outcomes examined. Thus we aimed to enroll patients with minimal risk factors that may interfere with ambulation, postdelivery analgesia, and quality of recovery. To limit potential confounding attributed to parity-related differences in postdelivery pain severity,[24–27] we restricted the population of interest to mothers having their first or second delivery (parity = zero, or parity = one with one live child), as we knew *a priori* that a third cesarean delivery is very rare at our institution. The primary source of the data used in this study was the number of steps taken by each patient, as registered by the wrist-worn activity trackers. Pain scores and QoR data were collected using a patient diary, while analgesic consumption and demographic data were collected from the medical records.

Eligibility

Nulliparous patients having their first elective cesarean delivery or uncomplicated vaginal delivery and uniparous patients having their second elective cesarean delivery or uncomplicated vaginal delivery were enrolled in this study. Patients delivering by elective cesarean delivery were considered eligible if delivery was performed using a lower-segment cesarean section (Pfannenstiel) and completed under a spinal anesthetic inclusive of intrathecal morphine. Patients delivering vaginally were considered eligible if a lumbar epidural was administered for labor analgesia and if patients did not require assisted delivery. We excluded all high-risk pregnancies including (1) preeclampsia; (2) hemolysis, elevated liver enzymes, low platelet count (HELLP) syndrome; (3)

significant psychiatric or mental disorder, including active anxiety/depression; (4) diabetes mellitus or gestational diabetes; (5) maternal age of more than 42; (6) pyelonephritis; (7) morbid obesity (body mass index [BMI] of at least 40 kg/m^2); (8) known congenital anomalies; (9) active sexually transmitted infections; (10) polyhydramnios or oligohydramnios; (11) multiple gestation; (12) premature births; and (13) deliveries where the newborn required extended observation or intensive care. We also excluded patients with potential confounders that may entail atypical analgesic requirements, postpartum pain, and postpartum ambulation, such as intolerance to components of the multimodal analgesic regimen used or preexisting chronic pain, and patients who experienced delivery complications, such as postpartum hemorrhage or third-degree tears during vaginal delivery. Furthermore, patients who experienced suboptimal anesthetic or analgesic techniques, *i.e.*, required supplementation or conversion from spinal to general anesthesia for cesarean delivery, or had a persistent patchy labor epidural block, as evidenced by frequent bolusing (3 or more), or required resiting of the epidural catheter for vaginal delivery, were also excluded. Patients who used combined spinal epidural for labor analgesia were not included, because this modality is reserved at our institution for women (especially multiparous) in active labor, precipitous labor, or with epidural failure. Finally, patients who had a labor epidural converted to provide surgical anesthesia for a cesarean delivery were also ineligible. To ensure accurate responses to survey questions, recruitment was restricted to English-speaking patients.

Predelivery Procedures

Patients were contacted for possible involvement in this study after admission to the labor and delivery suite. Those scheduled for elective cesarean delivery were approached in the triage area, before delivery, whereas those having a vaginal delivery were approached in their labor and delivery room, immediately after delivery. The aim of the study was explained, and patients were familiarized with the use of the wrist-worn activity trackers, the patient diary to document postdelivery pain severity, and the QoR-15 tool. Verbal approval for participation in the study was sought from interested patients. The water-resistant nature of the bracelets was emphasized, and patients were instructed to wear the activity tracker continuously around the wrist of their nondominant hand for the full 24-h observation period. Baseline information such as maternal age, BMI, fetal weight, and feeding plans (*i.e.,* breastfeeding or formula) were collected.

Postdelivery Procedures

Patients were met immediately after delivery to (1) obtain informed consent, (2) provide the patient diary, (3) be fitted with the activity trackers (UP by Jawbone Fitness Trackers, USA), and (4) be reminded of the study procedures. Subsequently, the trackers and diaries were collected at 24 h postdelivery. Activity trackers were synchronized to the UP by the Jawbone smartphone application immediately after collection to avoid registering the assessor's movement as steps, and the patient's number of steps during the first 24 h postdelivery was documented. All trackers were reset and cleaned with a sterilizing solution before each use.

Care Standard

The standardized institutional postdelivery pain management protocol was used for all patients. For cesarean delivery, this included 0.1 mg of morphine and 0.015 mg of fentanyl administered intrathecally, as part of the spinal anesthetic, 500 mg of naproxen suppository immediately after the cesarean section, 500 mg of oral naproxen twice daily for 1 day, and 1,000 mg of acetaminophen every 6 h for 3 days. For vaginal delivery, parturients received patient-controlled epidural analgesia using a 0.08% ropivacaine with 2 μg ml^{-1} fentanyl solution, as per routine institutional practice. After vaginal delivery, patients received 200 mg of oral ibuprofen every 6 h for 1 day, and 500 mg of acetaminophen every 6 h for 3 days. Catheters were removed 1 h after the placenta was delivered, if the mother was in a stable condition. For breakthrough pain, 5 to 10 mg of oral morphine was available on demand for both patient populations. These orders are revised and modified, as needed, by acute pain service on day 2 postdelivery.

Study Design

Patients who had a cesarean delivery were compared to those who delivered vaginally on postpartum ambulation, pain relief, and QoR. For these comparisons, the data were modeled using a multivariable regression analysis with mode of delivery as an independent variable. The baseline/demographic predictors considered for the multivariable model included six *a priori* identified potential confounders and/or risk factors that may influence postdelivery ambulation and/or pain, including (1) age, (2) BMI, (3) fetal weight, (4) breastfeeding, (5) parity, and (6) delivery time (morning *vs.* afternoon cesarean delivery). Multivariable regression modeling was used to examine whether these potential confounders were significant predictors of the patients' total number of steps during the first 24 h postdelivery. All factors significant at $P < 0.2$ were retained in the model. Furthermore, we have performed an additional *post hoc* exploration of the correlation between ambulation and the other outcomes measures, specifically pain and quality of recovery.

Outcome Measures

Postpartum Ambulation. Ambulation, measured by the number of steps taken during the first 24 h postdelivery, was designated as a primary outcome and was captured by wrist-worn activity trackers and subsequently stratified for intervals of 0 to 6, 6 to 12, 12 to 18, and 18 to 24 h. The UP by Jawbone activity tracker permits measuring the number of steps taken along with the times at which these

steps were taken (appendix 1). Data collected by the tracker were accessible through the manufacturer's mobile application, available for download on smartphone devices. Activity trackers *per se* have been shown to be a valid and reliable tool in objectively measuring user steps in the clinical setting.[28–30] They can also monitor user steps and sleep patterns and provide goal setting options for weight, nutrition, and fitness.[31] For the purposes of our study, user steps were the only data retrieved.

Postdelivery Analgesia. Rest and dynamic (walking, or sitting up if walking is not possible) pain severity scores at 2, 6, 12, 18, and 24 h postpartum were documented by patients in the diary using a visual analog scale (VAS; 0 = no pain at all, 10 = worst pain imaginable) score. The additional breakthrough analgesic consumption (mg of morphine) during the first 24 h postdelivery was also documented.

Quality of Recovery. The patient diary also included two copies of the QoR-15 questionnaire to be completed at 12 and 24 h postdelivery to assess early postdelivery recovery. The QoR-15 is a validated patient-centered tool that evaluates physical and emotional well-being through five dimensions of health including pain, physical comfort, physical independence, emotional support, and psychologic support.[22] The questionnaire consists of 15 questions, each scored from 0 to 10 for a maximal score of 150. A difference of 8 units in the global QoR-15 score is considered a clinically important difference in early postoperative recovery.[32]

Analysis

We used multivariable regression to evaluate the association between the primary outcome, postdelivery ambulation, and the mode of delivery. We designated a P value < 0.05 as the threshold of statistical significance for the associations examined. We used the Bonferroni–Holm correction to adjust for repeated outcome measurements.[33] Continuous outcome data were expressed as means (95% CI). Ordinal outcome data describing QoR scores and pain VAS scores were treated as continuous data and reported as means (95% CI). We used the Student's t tests or the Mann–Whitney U tests, as appropriate, to compare continuous outcomes. Categorical variables were expressed as proportions (percentages), and compared using the chi-square tests or Fisher exact tests, as appropriate. Finally, the exploration of the correlation between ambulation (independent variable) and pain severity scores (rest and dynamic), as well as QoR scores, was performed *post hoc* by calculating the Spearman's correlation coefficient. The data were analyzed using R version 3.2.3 (R Foundation for Statistical Computing, Austria).

Sample Size Calculation

To test the hypothesis that vaginal-delivery parturients have better ambulation than cesarean-delivery parturients, we performed a two-sided test of superiority of the number of steps during the first 24 h at the 5% significance level. Based on our preliminary institutional data, we estimated the means ± SD of the number of steps during the first 24 h after vaginal delivery to be 1,000 ± 250 steps. Assuming that a 20% difference in the total number of steps would be clinically meaningful, we calculated that a sample of at least 25 patients per group (50 in total) would provide 80% power with a type I error estimate of 0.05 to detect superiority of ambulation.

Results

We screened all parturients who delivered by cesarean delivery or vaginal delivery during regular work hours (8:00 to 16:00) of the time period of interest. We identified 684 potentially relevant deliveries performed between July 2015 and December 2016. Of these, 511 records did not meet the inclusion criteria (fig. 1), and 173 patients were recruited; complete data were available for all recruited patients: 76 in the cesarean-delivery group and 97 in the vaginal-delivery group. All 173 patients were included in the final analysis. Table 1 summarizes the baseline characteristics for both study groups. There were no significant differences in patient baseline characteristics. Multiple regression analysis confirmed that the six predefined potential confounders of postpartum ambulation were all significant predictors of the total number of steps during the first 24 h postdelivery (appendix 2).

Ambulation

The numbers of steps registered by the activity trackers in this cohort suggested that vaginal delivery is associated with greater ambulation (44% more, P < 0.0001) during the first 24 h postpartum. The mean (95% CI) of the number of steps during the first 24 h was 1,205 steps (1,120, 1,290) in the vaginal-delivery group, compared to 835 steps (748, 922) in the cesarean-delivery group. Table 2 summarizes the outcome results for both groups. The difference between the

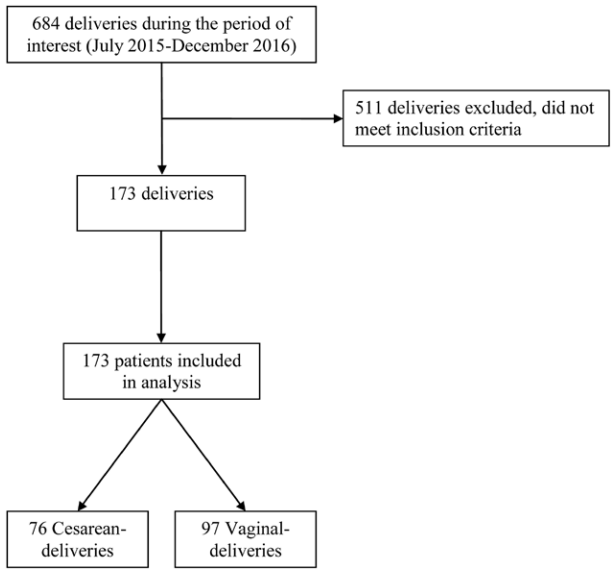


Fig. 1. Flow diagram of case selection.

two groups (vaginal delivery – cesarean delivery) was 370 steps (250, 490).

When the total number of steps for each study group in this cohort was stratified into 6-h intervals, it was noted that vaginal delivery was associated with significantly greater number of steps during the 0 to 6 h (P = 0.005), 6 to 12 h (P = 0.003), and 18 to 24 h (P = 0.01) intervals, suggesting better early ambulation in the vaginal-delivery group (fig. 2). The difference during the 12 to 18-h interval was not statistically significant (P = 0.33), which may suggest a lack of difference in ambulation between the two groups during night time. Almost 70% of the total difference (258 of 370 steps) was attributed to the combined 12 to 24-h interval. Figure 3 illustrates the interval frequency distribution of ambulation.

Postdelivery Analgesia

Except at 2 h postdelivery, where vaginal delivery seemed to be associated with worse rest and dynamic pain severity in this cohort, with differences in VAS scores equivalent to 1.3 (0.3, 2.3; P = 0.003) and 1.6 (0.2, 3.0; P = 0.03), respectively (table 2), there was no statistically significant difference in rest or dynamic pain severity scores between the two modes of delivery at all other time points examined. Although figure 4 seemed to suggest that patients in the vaginal-delivery group also had worse pain during the 6 to 24-h interval, we could not detect any statistically significant differences in pain scores between the two groups beyond 2 h.

Table 1. Baseline Characteristics and Outcome Results of the Prospective Cohort

Baseline Characteristics	Cesarean Delivery (n = 76)	Vaginal Delivery (n = 97)	*P* Value
Age (yr)	33 (9)	31 (10)	0.15
BMI (kg/m^2)	32.2 (8.8)	31.4 (10.4)	0.60
Fetal weight (g)	3,428 (902)	3,374 (918)	0.68
Breastfeeding (yes/no)	73/3	93/4	0.95
Parity (0/1)	47/29	56/41	0.58
Delivery time: (8:00–12:00/12:00–16:00)	40/36	49/48	0.78

The values are expressed as means (SD), means (95% CI), or number of patients.
BMI = body mass index.

Both groups had minimal opioid consumption (less than 1.0 mg of oral morphine) during the first 24 h, and the difference in consumption between the two groups was not statistically significant between parturients who had a cesarean delivery with spinal anesthesia and intrathecal morphine (0.1 mg) and parturients who had a vaginal delivery with epidural analgesia.

Quality of Recovery

The QoR evaluation using the patient diary in this cohort suggested that vaginal delivery was associated with superior quality of early postdelivery recovery, compared to the cesarean delivery, with differences in QoR-15 scores (vaginal delivery – cesarean delivery) equivalent to 9.2 (0.6, 17.8; P = 0.02) at 12 h and 8.2 (0.1, 16.3; P = 0.045) at 24 h (table 2). These differences are considered clinically important[32] and were attributable to differences in the physical comfort and physical independence dimensions of the QoR-15 (fig. 5). The two modes of delivery were associated with similar scores in the pain, emotional state, and psychologic support dimensions. *Post hoc* exploration of the correlation between pain as well as QoR (as dependent variables) and ambulation (number of steps) using the current data suggests the presence of strong positive correlations between pain (dynamic only) and ambulation (r = 0.64, P = 0.006), as well as between QoR and ambulation (r = 0.77, P < 0.001).

Finally, none of the participants of this cohort reported any difficulties in completing the patient diary or the need to remove the activity trackers from their wrists during the observation period. Furthermore, the use of activity trackers was not associated with any technical challenges or inconveniences, and the captured ambulation data were successfully retrieved for all patients, suggesting the acceptability and practicality of using activity trackers in this patient population.

Discussion

Our findings suggest that cesarean delivery is associated with reduced ambulation, as measured by the number of steps during first 24 h postdelivery, compared to vaginal delivery. This finding is notable considering that both vaginal delivery and cesarean delivery were associated with similarly effective postpartum pain control during the first 24 h postdelivery, as measured by pain scores and opioid consumption, and in the presence of an institutional policy encouraging early

Table 2. Outcome Results of the Prospective Cohort

Outcome	Cesarean Delivery (n = 76)	Vaginal Delivery (n = 97)	Difference	*P* Value*
Steps during first 24 h	835 (381)	1,205 (422)	370 [250, 490]	< 0.0001
Rest pain at 2 h	0.7 (2.9)	2.0 (4.0)	1.3 [0.3, 2.3]	0.003
Dynamic pain at 2 h	1.2 (4.8)	2.8 (4.5)	1.6 [0.2, 3.0]	0.03
Quality of recovery score at 12 h	120.0 (28.4)	129.2 (28.8)	9.2 [0.6, 17.8]	0.02
Quality of recovery score at 24 h	123.1 (27.1)	131.3 (26.8)	8.2 [0.1, 16.3]	0.045

The values are expressed as means (SD) or means (95% CI).
*The Bonferroni–Holm correction has been used to adjust the threshold of statistical significance for multiple measurements.

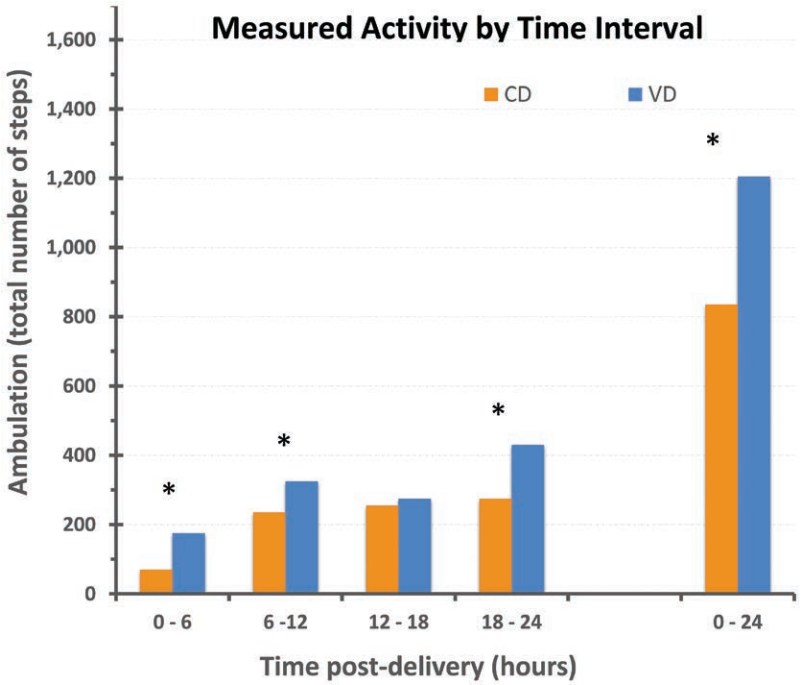


Fig. 2. Bar plot of the number of steps during the first 24 h, stratified into 6-h intervals. *Statistical significance (after Bonferroni–Holm adjustment). CD = cesarean delivery; VD = vaginal delivery.

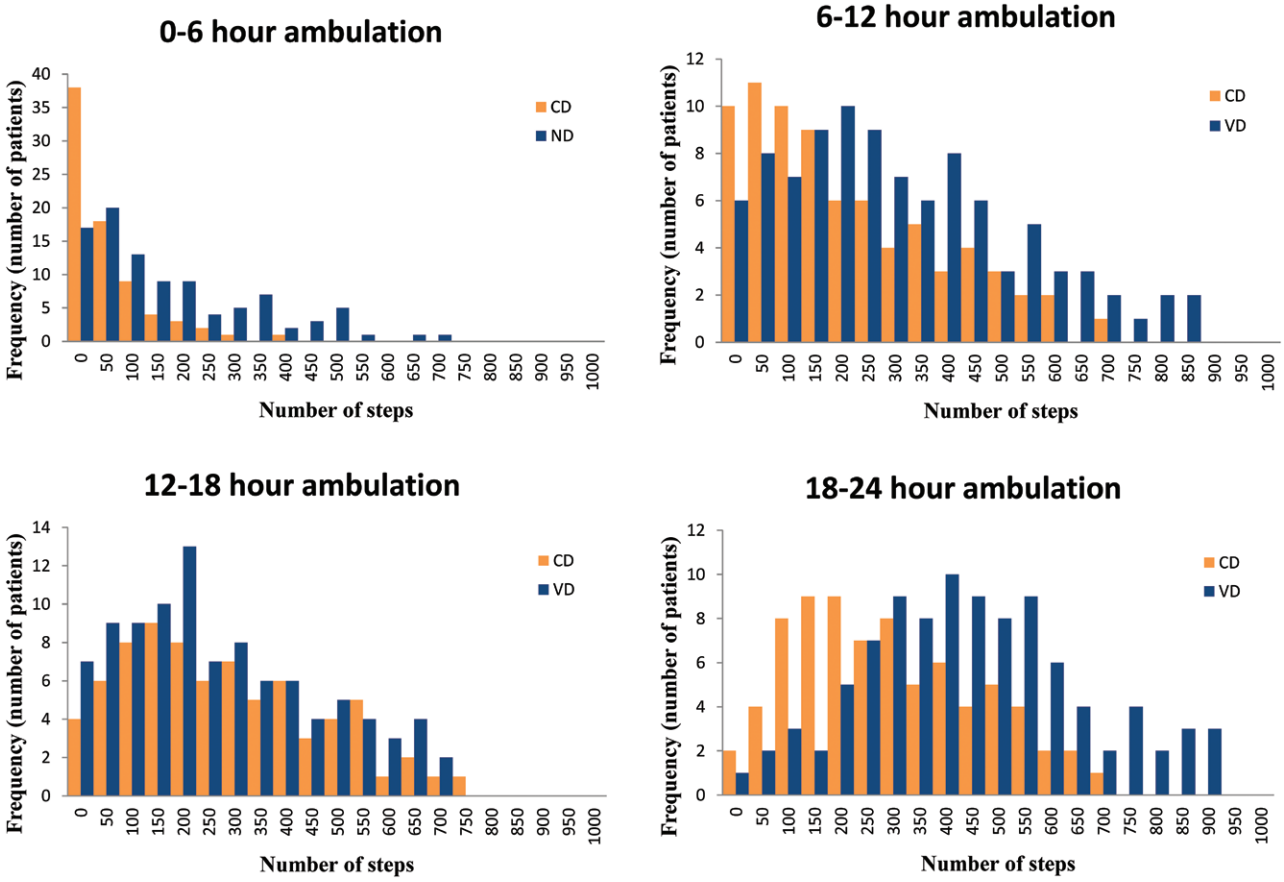


Fig. 3. Interval frequency distribution by ambulation. CD = cesarean delivery; VD = vaginal delivery.

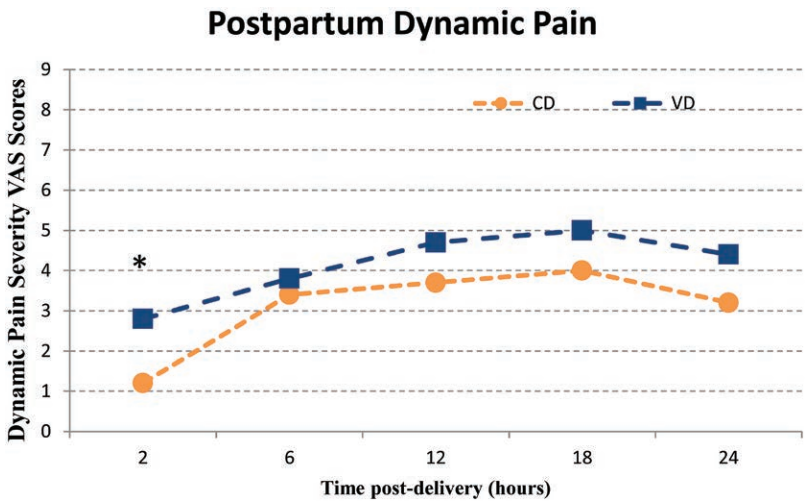
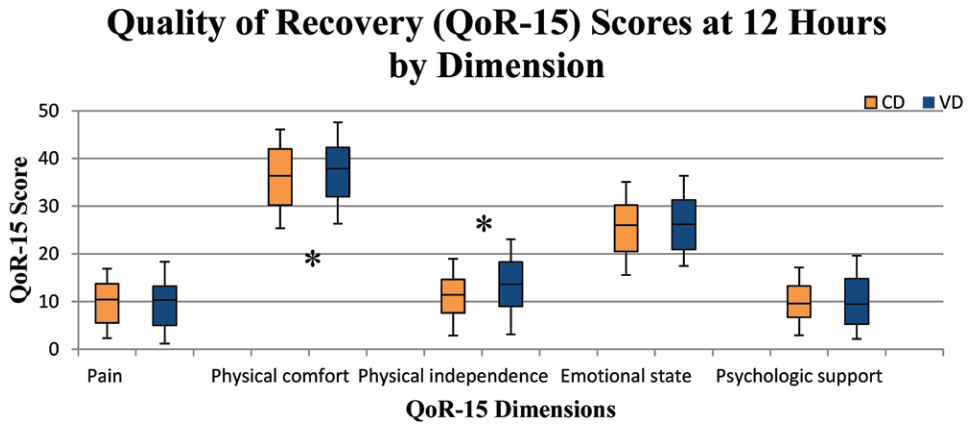


Fig. 4. Plot of the dynamic pain severity visual analog pain scores. *Circles* and *squares* represent the mean values. *Statistical significance (after Bonferroni–Holm adjustment). CD = cesarean delivery; VAS = visual analog scale; VD = vaginal delivery.



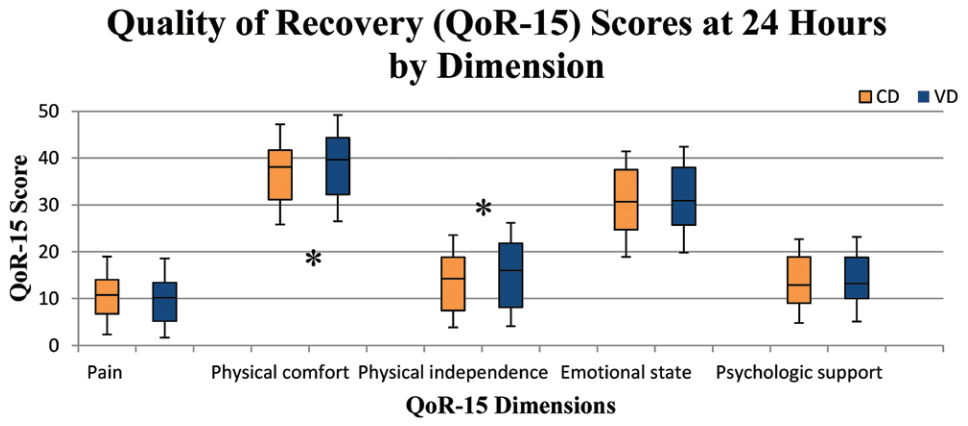


Fig. 5. Box plot of the dimensions of the quality of recovery (QoR-15) scores at 12 and 24 h postdelivery. Median values are shown as *solid lines* within boxes of 25th and 75th percentile values. The *whiskers* represent 5th and 95th percentile values. The data were compared using the Mann–Whitney U test. *Statistical significance (after a Bonferroni–Holm adjustment). CD = cesarean delivery; QoR = quality of recovery; VD = vaginal delivery.

ambulation after cesarean delivery. Additionally, vaginal delivery was associated with superior QoR at 12 and 24 h postdelivery. Importantly, our study demonstrates the feasibility of using the activity trackers to objectively measure the degree of mobility and evaluate early functional recovery among postpartum mothers, as a model population that receives regional (neuraxial) anesthesia and analgesia interventions. These findings set the stage for adopting early

ambulation as a performance indicator of perioperative care and enhanced functional recovery.

The use of activity trackers has been explored in the thoracic and orthopedic surgery populations[34,35] to evaluate postoperative modifications to activity level and lifestyle, with the aim of enhancing long-term patient outcomes. In the first study,[34] cardiac surgery patients were monitored for 5 days after intensive care unit discharge; in the second study,[35] hip-replacement patients were monitored for 1 month after home discharge. Both studies used wireless accelerometery activity trackers requiring real-time synchronization to evaluate the effect of certain parameters, such as surgical technique, disposition, or BMI, on medium-to-long–term mobility. In contrast, our study is novel in that it used commercially available activity trackers to measure early postpartum ambulation and to objectively demonstrate the difference in ambulation between vaginal delivery and cesarean delivery during the first 24 h postpartum. Differences in ambulation were not limited to the 0 to 6-h interval, suggesting that mothers having a cesarean delivery continue to ambulate less than their vaginal-delivery counterparts for at least 1 day postdelivery, despite complete regression of spinal anesthesia. These differences may be inherent to the mode of delivery itself. For example, vaginal delivery is known to be more psychologically tolerated compared to cesarean delivery[36]; it is also associated with better immediate maternal satisfaction,[37] as well as shorter time to newborn[38] interaction and care. In contrast, cesarean delivery may be associated with wound guarding and fear of activity-related pain. Additional factors such as insufficient hospital and staff resources to assist in ambulation, lack of communication,[19] poor patient compliance,[15] and presence of support persons with parturients have also been proposed as common barriers precluding early ambulation.

Both rest and dynamic pain severity scores, as well as the pain dimension of the QoR-15, suggested that vaginal delivery was associated with worse pain during the first 24 h postdelivery, although the difference reached statistical significance at 2 h postdelivery only. Although the difference at 2 h may be due to residual spinal anesthesia affecting the cesarean-delivery group, the trend of worse pain in the vaginal-delivery group may reflect a difference in uterine involution rates between vaginal delivery and cesarean delivery, as well as the analgesic effect of intrathecal morphine in the cesarean-delivery group. The minimal opioid consumption in both groups may signal opioid avoidance among lactating mothers, which reduces the clinical and research utility of this outcome measure in the postpartum population.

This study validated the use of the novel QoR-15 tool[22] in evaluating functional recovery in the postpartum population. It is generally accepted that QoR should closely correlate with pain control.[39] However, our cohort depicts two populations that had similar pain scores while maintaining clinically important differences in a well recognized measure of postoperative functional recovery. This observation may signal shortcomings of using pain scores and opioid consumption as the prime quality of care indicators in obstetric anesthesia and analgesia practice and underscores the growing role of functional recovery measures. This may be explained partially by analgesic avoidance and underreporting of pain in the postpartum population.[40] Notwithstanding the inconsistency between the QoR-15 scores and pain control, this finding invites a formal validation study of this scale in the postpartum population.

Enhanced functional recovery is becoming a prime success indicator of modern perioperative healthcare, and particularly anesthetic interventions.[41–44] To this end, quantifying ambulation for evaluative purposes presents challenges, because the traditional means of measuring ambulation have typically relied on self-reported activity by patients, which is characterized by low reliability and validity across the various self-reporting tools.[45–48] In addition, the dynamic and demanding nature of [our] inner city hospital makes it challenging for nurses and clinicians to actively monitor patients and ensure that early ambulation policies are being fully met. Activity trackers offer a simple, low-cost, low-burden, reliable way of measuring activity in real time. We found the wrist-worn trackers in specific to be well received by parturients because they did not interfere with activity, newborn care, or even showering, a notable advantage over those clipped to clothing. Minimizing the time and effort spent on follow-up is another advantage of these trackers if used in anesthesia research.

The findings of our study are subject to several limitations. First, the observational nature of our work supports conclusions about potential associations and not causal relationships, but this design is appropriate because randomization into vaginal delivery *versus* cesarean delivery and blinding are not feasible. To help address this issue, we set an eligibility criteria aimed at limiting the influence of confounding factors that may favor a certain mode of delivery and simultaneously influence postpartum pain or ambulation. This also served to improve the comparability of the study groups and reduce bias. Nonetheless, these exclusions *per se* may reduce the external validity (generalizability) of our findings. Second, it is important to point out that there is no "gold standard" or ideal activity tracker device identified for measuring ambulation and that most devices available have inherent limitations.[49] To that end, our findings may have been limited by potential errors in data collection and documentation. For example, interpreting upper extremity movement as actual ambulation is considered a drawback, to varying extents, in most commercially available wrist-worn activity trackers. The UP by Jawbone is among the least prone to such misinterpretation.[49] Nonetheless, the impact of any residual inaccuracy is not expected to bias our findings, because it introduces a systematic error that applies

to both groups. Third, certain factors, such as limiting recruitment to parturients delivering during regular work hours, may have introduced bias into our analysis. Some factors that may influence ambulation, such as the presence of a family member or support person, the nurse-to-parturient ratio, postpartum dizziness or sedation, pain catastrophization, heaviness of lochia, time to commence breastfeeding, time to removal of venous infusion, and newborn health condition, were not examined due to lack of data. Additional factors that may also influence ambulation but are specific to one population and not the other and thus could not be assessed include duration of spinal anesthesia (for cesarean delivery), duration of analgesia (or time to epidural catheter removal, for vaginal delivery), estimated surgical blood loss, and degree of vaginal tear. Fourth, limiting recruitment to uncomplicated first and second deliveries in a healthy population may further limit the generalizability of our findings. In addition, the findings may not necessarily apply to obstetric anesthesia practices where different analgesic regimens or ambulation guidelines are used. Fifth, we did not distinguish between abdominal wall and visceral components of pain among cesarean-delivery patients. Because pain after vaginal delivery is predominantly visceral, it would have been clinically insightful to compare this pain component in the two groups. Sixth, we did not specifically assess the sleep quality in our patients, but this important outcome was part of the physical comfort domain of the QoR-15. Finally, we are cognisant of the fact that the use of activity trackers in itself may have motivated ambulation among parturients and that our findings are applicable to the first postpartum day only and may not apply to ambulation beyond that time point.

In conclusion, our findings suggest that vaginal delivery is associated with better ambulation and enhanced functional recovery during the first 24 h postdelivery compared to cesarean delivery, despite similarly effective postpartum analgesia. Importantly, this study provides evidence of the feasibility of using activity trackers to evaluate early postoperative ambulation and functional recovery in populations receiving neuraxial anesthesia and analgesia interventions. Further research is needed to confirm our findings and also to validate the use of activity trackers in the postpartum population.

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Competing Interests

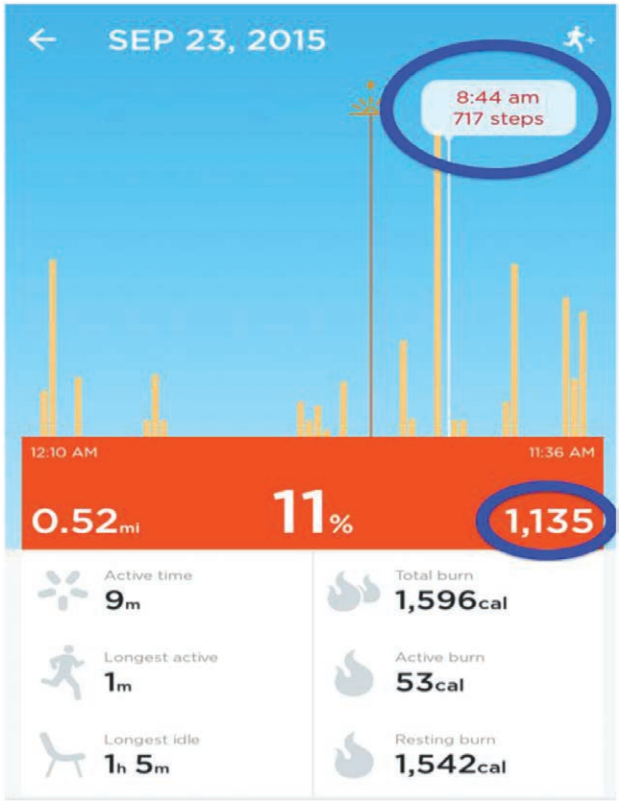
The authors declare no competing interests.

Correspondence

Address correspondence to Dr. Abdallah: St. Michael's Hospital, University of Toronto, 30 Bond Street, Toronto, Ontario M5B 1W8, Canada. AbdallahF@smh.ca. Information on purchasing reprints may be found at www.anesthesiology.org or on the masthead page at the beginning of this issue. ANESTHESIOLOGY's articles are made freely accessible to all readers, for personal use only, 6 months from the cover date of the issue.

Appendix 1: Technical Details

Five activity trackers were used for data collection. Each tracker was labeled (*i.e.*, T1, T2, T3, T4, and T5), and a separate email account and UP by Jawbone mobile application account was created for each bracelet. Parturient data (*i.e.*, sex, weight, height, date of birth) were entered before fitting the participants with fitness bracelets. Immediately after collection, the bracelets were synchronized to their corresponding UP Jawbone accounts through the UP smartphone application. The "number of steps" data within the 24-h observation period were documented immediately after recollecting the bracelets to avoid registering the assessor movement as steps. The mobile application interface permits obtaining the number of steps taken in specific time intervals (see screen capture below). The bracelets were reset using a hard reset to clear previous tracking data for each new patient, as per the manufacturer's suggestions.[31]



Appendix 2: Sensitivity Analysis

Table A2.1. Multivariable Regression Model for the Predefined Predictors ($P < 0.2$) of Postpartum Ambulation, as Measured by Total Number of Steps in First 24 h Postdelivery

	Parameter Estimate (95% CI)	Standard Error	*P* Value
Predictor of interest			
Mode of delivery (vaginal *vs.* cesarean)	+0.006 (0.001, 0.011)	0.0025	< 0.0001
Continuous predictors			
Age (yr)	−0.320 (−0.596, −0.044)	0.14	0.02
BMI (kg/m^2)	−0.180 (−0.318, −0.042)	0.07	0.01
Fetal weight (g)	−0.200 (−0.397, −0.003)	0.10	0.04
Categorical predictors			
Breastfeeding (yes/no)	−0.150 (−0.268, −0.032)	0.06	0.01
Parity (first baby/ second baby)	+0.010 (0.0001, 0.020)	0.005	0.047
Delivery time: morning (8:00–12:00) *vs.* afternoon (12:00–16:00)	−0.400 (−0.795, −0.005)	0.2	0.046

The values are presented as parameter estimates (95% CI), standard errors.

BMI = body mass index.

References

1. Boney O, Moonesinghe SR, Myles PS, Grocott MP: Standardizing endpoints in perioperative research. Can J Anaesth 2016; 63:159–68
2. Brattwall M, Warren-Stomberg M, Jakobsson J: Outcomes, measures and recovery after ambulatory surgery and anaesthesia: A review. Curr Anesthesiol Rep 2014; 4:334–41
3. Jammer I, Wickboldt N, Sander M, Smith A, Schultz MJ, Pelosi P, Leva B, Rhodes A, Hoeft A, Walder B, Chew MS, Pearse RM; European Society of Anaesthesiology (ESA) and the European Society of Intensive Care Medicine (ESICM); European Society of Anaesthesiology; European Society of Intensive Care Medicine: Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European Perioperative Clinical Outcome (EPCO) definitions: A statement from the ESA-ESICM joint taskforce on perioperative outcome measures. Eur J Anaesthesiol 2015; 32:88–105
4. Myles PS, Grocott MP, Boney O, Moonesinghe SR; COMPAC-StEP Group: Standardizing end points in perioperative trials: Towards a core and extended outcome set. Br J Anaesth 2016; 116:586–9
5. Neville A, Lee L, Antonescu I, Mayo NE, Vassiliou MC, Fried GM, Feldman LS: Systematic review of outcomes used to evaluate enhanced recovery after surgery. Br J Surg 2014; 101:159–70
6. Brower RG: Consequences of bed rest. Crit Care Med 2009; 37(10 suppl):S422–8
7. Morris BA, Benetti M, Marro H, Rosenthal CK: Clinical practice guidelines for early mobilization hours after surgery. Orthop Nurs 2010; 29:290–318
8. Kalisch BJ, Lee S, Dabney BW: Outcomes of inpatient mobilization: A literature review. J Clin Nurs 2014; 23:1486–501
9. Alvarez MP, Foley KE, Zebley DM, Fassler SA: Comprehensive enhanced recovery pathway significantly reduces postoperative length of stay and opioid usage in elective laparoscopic colectomy. Surg Endosc 2015; 29:2506–11
10. Pashikanti L, Von Ah D: Impact of early mobilization protocol on the medical-surgical inpatient population: An integrated review of literature. Clin Nurse Spec 2012; 26:87–94
11. Allen C, Glasziou P, Del Mar C: Bed rest: A potentially harmful treatment needing more careful evaluation. Lancet 1999; 354:1229–33
12. Haines KJ, Skinner EH, Berney S; Austin Health POST Study Investigators: Association of postoperative pulmonary complications with delayed mobilisation following major abdominal surgery: An observational cohort study. Physiotherapy 2013; 99:119–25
13. Chapman JS, Roddy E, Ueda S, Brooks R, Chen LL, Chen LM: Enhanced recovery pathways for improving outcomes after minimally invasive gynecologic oncology surgery. Obstet Gynecol 2016; 128:138–44
14. Castelino T, Fiore JF Jr, Niculiseanu P, Landry T, Augustin B, Feldman LS: The effect of early mobilization protocols on postoperative outcomes following abdominal and thoracic surgery: A systematic review. Surgery 2016; 159:991–1003
15. Liebermann M, Awad M, Dejong M, Rivard C, Sinacore J, Brubaker L: Ambulation of hospitalized gynecologic surgical patients: A randomized controlled trial. Obstet Gynecol 2013; 121:533–7
16. Karlström A, Engström-Olofsson R, Norbergh KG, Sjöling M, Hildingsson I: Postoperative pain after cesarean birth affects breastfeeding and infant care. J Obstet Gynecol Neonatal Nurs 2007; 36:430–40
17. Say L, Chou D, Gemmill A, Tunçalp Ö, Moller AB, Daniels J, Gülmezoglu AM, Temmerman M, Alkema L: Global causes of maternal death: A WHO systematic analysis. Lancet Glob Health 2014; 2:e323–33
18. Berlin JE, Storti KL, Brach JS: Using activity monitors to measure physical activity in free-living conditions. Phys Ther 2006; 86:1137–45
19. McLeod RS, Aarts MA, Chung F, Eskicioglu C, Forbes SS, Conn LG, McCluskey S, McKenzie M, Morningstar B, Nadler A, Okrainec A, Pearsall EA, Sawyer J, Siddique N, Wood T: Development of an enhanced recovery after surgery guideline and implementation strategy based on the knowledge-to-action cycle. Ann Surg 2015; 262:1016–25
20. Yates BC, Pozehl B, Kupzyk K, Epstein CM, Deka P: Are heart failure and coronary artery bypass surgery patients meeting physical activity guidelines? Rehabil Nurs 2016:1–7
21. Macht R, Wong K, Orden Kv, Rosenkranz P, McAneny D, Hess D: Utilizing activity trackers to increase postoperative ambulation: A novel strategy to quantify ambulation and decrease bariatric surgery postoperative complications (abstract). Presented at the Graduate Research Symposium Boston University, Boston, MA, March 31, 2015
22. Stark PA, Myles PS, Burke JA: Development and psychometric evaluation of a postoperative quality of recovery score: The QoR-15. Anesthesiology 2013; 118:1332–40
23. Elm Ev, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP: Strengthening the reporting of observational studies in epidemiology (STROBE) statement: Guidelines for reporting observational studies. BMJ 2007; 335:806–8
24. Deussen AR, Ashwood P, Martis R: Analgesia for relief of pain due to uterine cramping/involution after birth. Cochrane Database Syst Rev 2011; 5:CD004908
25. Holdcroft A, Snidvongs S, Cason A, Doré CJ, Berkley KJ: Pain and uterine contractions during breast feeding in the immediate post-partum period increase with parity. Pain 2003; 104:589–96
26. Macarthur AJ, Macarthur C: Incidence, severity, and determinants of perineal pain after vaginal delivery: A prospective cohort study. Am J Obstet Gynecol 2004; 191:1199–204
27. Murray A, Holdcroft A: Incidence and intensity of postpartum lower abdominal pain. BMJ 1989; 298:1619
28. Evenson KR, Goto MM, Furberg RD: Systematic review of the validity and reliability of consumer-wearable activity trackers. Int J Behav Nutr Phys Act 2015; 12:159

29. Ferguson T, Rowlands AV, Olds T, Maher C: The validity of consumer-level, activity monitors in healthy adults worn in free-living conditions: A cross-sectional study. Int J Behav Nutr Phys Act 2015; 12:42
30. Kooiman TJ, Dontje ML, Sprenger SR, Krijnen WP, van der Schans CP, de Groot M: Reliability and validity of ten consumer activity trackers. BMC Sports Sci Med Rehabil 2015; 7:24
31. Jawbone. Jawbone Support. Available at: https://jawbone.com/support/up. Accessed August 20, 2016
32. Myles PS, Myles DB, Galagher W, Chew C, MacDonald N, Dennis A: Minimal clinically important difference for three quality of recovery scales. Anesthesiology 2016; 125:39–45
33. Holm S: A simple sequentially rejective multiple test procedure. Scand J Statistics 1979; 6:65–70
34. Cook DJ, Thompson JE, Prinsen SK, Dearani JA, Deschamps C: Functional recovery in the elderly after major surgery: Assessment of mobility recovery using wireless technology. Ann Thorac Surg 2013; 96:1057–61
35. Toogood PA, Abdel MP, Spear JA, Cook SM, Cook DJ, Taunton MJ: The monitoring of activity at home after total hip arthroplasty. Bone Joint J 2016; 98-B:1450–4
36. Schindl M, Birner P, Reingrabner M, Joura E, Husslein P, Langer M: Elective cesarean section vs. spontaneous delivery: A comparative study of birth experience. Acta Obstet Gynecol Scand 2003; 82:834–40
37. DiMatteo MR, Morton SC, Lepper HS, Damush TM, Carney MF, Pearson M, Kahn KL: Cesarean childbirth and psychosocial outcomes: A meta-analysis. Health Psychol 1996; 15:303–14
38. Rowe-Murray HJ, Fisher JR: Operative intervention in delivery is associated with compromised early mother-infant interaction. BJOG 2001; 108:1068–75
39. Wu CL, Rowlingson AJ, Partin AW, Kalish MA, Courpas GE, Walsh PC, Fleisher LA: Correlation of postoperative pain to quality of recovery in the immediate postoperative period. Reg Anesth Pain Med 2005; 30:516–22
40. Hofmeyr GJ, Nikodem VC, Wolman WL, Chalmers BE, Kramer T: Companionship to modify the clinical birth environment: Effects on progress and perceptions of labour, and breastfeeding. Br J Obstet Gynaecol 1991; 98:756–64
41. Myles PS: Perioperative outcomes: Are we asking the right questions? Can J Anaesth 2016; 63:138–41
42. Porter ME, Larsson S, Lee TH: Standardizing patient outcomes measurement. N Engl J Med 2016; 374:504–6
43. Kehlet H, Dahl JB: Anaesthesia, surgery, and challenges in postoperative recovery. Lancet 2003; 362:1921–8
44. Wu CL, Fleisher LA: Outcomes research in regional anesthesia and analgesia. Anesth Analg 2000; 91:1232–42
45. Ahmad S, Harris T, Limb E, Kerry S, Victor C, Ekelund U, Iliffe S, Whincup P, Beighton C, Ussher M, Cook DG: Evaluation of reliability and validity of the General Practice Physical Activity Questionnaire (GPPAQ) in 60–74 year old primary care patients. BMC Fam Pract 2015; 16:113
46. Appelboom G, Yang AH, Christophe BR, Bruce EM, Slomian J, Bruyère O, Bruce SS, Zacharia BE, Reginster JY, Connolly ES Jr: The promise of wearable activity sensors to define patient recovery. J Clin Neurosci 2014; 21:1089–93
47. Hekler EB, Buman MP, Haskell WL, Conway TL, Cain KL, Sallis JF, Saelens BE, Frank LD, Kerr J, King AC: Reliability and validity of CHAMPS self-reported sedentary-to-vigorous intensity physical activity in older adults. J Phys Act Health 2012; 9:225–36
48. Tierney M, Fraser A, Kennedy N: Criterion validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF) for use in patients with rheumatoid arthritis: comparison with the SenseWear Armband. Physiotherapy 2015; 101:193–7
49. Storm FA, Heller BW, Mazzà C: Step detection and activity recognition accuracy of seven physical activity monitors. PLoS One 2015; 10:e0118723