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Wearable activity sensors and early pain after total joint arthroplasty

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Material and methods

Twenty adult patients undergoing unilateral primary total hip arthroplasty (n = 12) or total knee arthroplasty (n = 8) were enrolled in an IRB-approved prospective observational pilot cohort at a single academic institution. Access to a smartphone for sensor data upload and ability to complete survey instruments were required. A wearable activity sensor (FitBit Flex™, Fitbit Corp, San Francisco, CA) and in-person training on wear, use, and data upload were provided at least 4 weeks before surgery. Patients were instructed to wear the sensor through 8 weeks after surgery. The accuracy of this sensor for medical research has been previously validated [6]. Deidentified and encrypted sensor data were securely and automatically collected in compliance with the Health Insurance Portability and Accountability Act using smartphone upload to the manufacturer’s proprietary platform, available to the study team via a secure research server. Daily measures of steps, distance, floors climbed, calories expended, and active minutes were collected. Any daily activity indicated sensor use. Preoperative and 6-week postoperative scores for pain (0-10), Veterans RAND 12-item index (VR12), Knee Injury and Osteoarthritis Outcome Score Junior (KOOS Jr), and Hip Disability and Osteoarthritis Score Junior (HOOS Jr) were collected. Two patient groups were identified by k-means cluster analysis for changes in activity measures before vs
after surgery. Outcomes between activity clusters were then compared using \( \chi^2 \) test for categorical variables and Mann-Whitney U test for continuous variables. Linear regression was used to assess bias. Data were analyzed using STATA 15 MP (STATA Corp, College Station, TX).

Results

No sensors were lost or required replacement. Mean device wear was 13.5 days preoperatively and 62 days postoperatively. Daily sensor use was 85% of days before and 88% after surgery. Cluster analysis was 13.5 days preoperatively and 62 days postoperatively. Daily sensor use was 85% of days before and 88% after surgery. Outcomes between activity clusters were then compared using \( \chi^2 \) test for categorical variables and Mann-Whitney U test for continuous variables. Linear regression was used to assess bias. Data were analyzed using STATA 15 MP (STATA Corp, College Station, TX).

Discussion

We show that post hoc data analysis of wearable sensor information objectively identifies similar patients progressing along divergent pathways in postoperative recovery from standardized surgical interventions. Cluster analysis of data from a consumer-level wearable sensor stratified patients by change in activity attributable to primary TJA, identifying that patients who became more sedentary early in their recovery reported subjectively greater and clinically significant improvements in pain. Conversely, postoperative patients who quickly met or exceeded their preinjury level of activity did not report early pain reduction or perceive clinically relevant improvement in their mobility or mental state. Aggressive activity early in recovery from TJA leads to “overdoing-it,” with aggravated pain and functional setbacks. We confirm that wearable sensors are feasible for passively, continuously, and remotely monitoring patients recovering from TJA.

Combining wearable sensor technologies with real-time statistical data analysis could “flip the clinic,” using insights from live information to trigger outpatient contact or coordinate follow-up based on concerning trends in objective patient behavior. We observed excellent outpatient compliance with sensor wear, minimal gaps in data collection, and no device malfunctions during the study period. Wearable sensors reasonably estimate results of accepted functional tests such as the timed up-and-go test [7]. Analyzing outpatient sensor information to guide medical decisions would represent a paradigm shift from traditional strategies based on rigid follow-up schedules, untriggered patient contact, and waiting for patients to call to report a problem to more timely care, with potential clinical benefits from shorter delays to interventions. This study is strengthened by prospective design and the use of a previously validated device with 81%-93% accuracy for running, walking, and stair activity [5]. Limitations include an underpowered sample size and short follow-up dictated by pilot grant funding; 80 patients would have been required for 80% power to detect minimal clinically important differences in pain and brief HOOS/KOOS Jr scores [8]. A causative relationship between postoperative pain and activity cannot be determined from these data. However, the results of this pilot study do suggest a correlation. Further study is warranted to identify sensed data that correlate with specific stiffness, infectious, mechanical, or other postoperative problems.

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Table 1

| Patient characteristics | Minimally changed activity | Decreased activity | P-value |
|-------------------------|----------------------------|--------------------|---------|
|                         | n = 15                     | IQR                | n = 5   | IQR                |         |
| Age (y)                 | 63.0 [58.0-68.0]            | 67.0 [67.0-67.0]    | .150    |
| Male sex                | 4 26.7%                    | 3 60%              | .176    |
| Total hip arthroplasty  | 9 60%                      | 3 60%              | 1.000   |
| ASA                     | 2.0 [2.0-2.0]               | 2.0 [2.0-2.0]      | .727    |
| Body mass index (kg/m²) | 29.9 [23.4-32.4]            | 25.8 [24.1-28.1]   | .541    |

IQR, interquartile range; ASA, American Society of Anesthesiologists physical status classification.

Table 2

| Objective activity and patient reported measures | Minimally changed activity | Decreased activity | P-value |
|------------------------------------------------|----------------------------|--------------------|---------|
| Activity or patient reported measure | n = 15 | IQR | n = 5 | IQR |         |
| ΔSteps                                  | 286.1 [14.9 to 1587.3]     | -3004.1 [-4485.9 to 2658.8] | .001 |
| ΔMiles walked                           | 0.1 [0.0 to 0.6]           | -1.4 [-2.0 to 1.4]       | .001   |
| ΔFloors climbed                        | 0.2 [-0.9 to 3.0]          | -2.2 [-8.7 to 0.7]       | .407   |
| ΔCalories (Kcal)                        | 10.4 [-70.0 to 94.8]       | -32.1 [-568.2 to 286.2]  | .008   |
| ΔVery active (min)                      | 0.1 [-0.5 to 0.3]          | -5.1 [-6.3 to 5.0]       | .026   |
| ΔFairly active (min)                    | 1.8 [-1.6 to 2.6]          | -9.1 [-20.3 to 7.8]      | .016   |
| ΔLightly active (min)                   | 7.7 [-21.6 to 35.3]        | -58.4 [-83.2 to 41.1]    | .016   |
| ΔSedentary (min)                        | 16.4 [-106.2 to 150.5]     | 85.8 [65.4 to 131.6]     | .089   |
| Pain baseline                           | 5.0 [3.0 to 7.0]           | 7.5 [6.0 to 8.0]         | .141   |
| ΔPain 6 wk                              | -2.0 [-3.0 to 0.2]         | -5.5 [-4.0 to 6.0]       | .030   |
| VR12 Physical baseline                  | 29.8 [25.3 to 36.9]        | 40.8 [26.5 to 41.9]      | .239   |
| ΔVR12 Physical 6 wk                     | 6.1 [0.3 to 10.0]          | 5.4 [5.0 to 5.8]         | .855   |
| VR12 Mental baseline                    | 47.3 [40.7 to 59.3]        | 44.9 [43.5 to 57.3]      | .760   |
| ΔVR12 Mental 6 wk                       | 2.5 [-4.4 to 5.5]          | 7.2 [6.3 to 8.0]         | .144   |
| HOOS Jr baseline                        | 56.0 [56.0 to 58.9]        | 53.0 [43.3 to 61.8]      | .644   |
| ΔHOOS Jr 6 wk                           | 20.8 [11.5 to 24.8]        | 30.5 [30.5 to 30.5]      | .275   |
| KOOS Jr baseline                        | 44.8 [34.2 to 52.5]        | 55.8 [50.0 to 61.6]      | .243   |
| ΔKOOS Jr 6 wk                           | 18.2 [11.3 to 30.0]        | 23.3 [23.3 to 23.3]      | .770   |

Bold values indicate significance at P-value < .05.
IQR, interquartile range; ΔQ change between preoperative and postoperative daily median value; VR12, Veteran Rand 12-item index.
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References

[1] Fortin PR, Clarke AE, Joseph L, et al. Outcomes of total hip and knee replacement: preoperative functional status predicts outcomes at six months after surgery. Arthritis Rheum 1999;42:1722.

[2] Harding P, Holland A, Hinman R, Delany C. Hip and knee arthroplasty surgery does not change physical activity. J Sci Med Sport 2013;16:e46.

[3] Brander VA, Stulberg SD, Adams AD, et al. Ranawat Award Paper: predicting total knee replacement pain: a prospective, observational study. Clin Orthop Relat Res 2003;416:27.

[4] 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.

[5] Bahadori S, Immins T, Wainwright TW. A review of wearable motion tracking systems used in rehabilitation following hip and knee replacement. J Rehabil Assist Technol Eng 2018;5. 205566831877181.

[6] Feehan LM, Geldman J, Sayre EC, et al. Accuracy of Fitbit devices: systematic review and narrative syntheses of quantitative data. JMIR Mhealth Uhealth 2018;6:e10527.

[7] Saporito S, Brodie MA, Delbaere K, et al. Remote timed up and go evaluation from activities of daily living reveals changing mobility after surgery. Physiol Meas 2019;40:035004.

[8] Lyman S, Lee Y-Y, McLawhorn AS, Islam W, MacLean CH. What are the minimal and substantial improvements in the HOOS and KOOS and Jr versions after total joint replacement? Clin Orthop Relat Res 2018;476:2432.