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Authors

Patterson, Joseph T

Wu, Hao-Hua

Chung, Christopher C

et al.

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Brief communication

Wearable activity sensors and early pain after total joint arthroplasty

Joseph T. Patterson, MD *, Hao-Hua Wu, MD, Christopher C. Chung, BA, Ilya Bendich, MD, MBA, Jeffrey J. Barry, MD, Stefano A. Bini, MD

University of California San Francisco, San Francisco, CA, USA

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ABSTRACT

A prospective observational cohort of 20 primary total hip arthroplasty (n = 12) and total knee arthroplasty (n = 8) patients (mean age: 63 ± 6 years) was passively monitored with a consumer-level wearable activity sensor before and 6 weeks after surgery. Patients were clustered by minimal change or decreased activity using sensor data. Decreased postoperative activity was associated with greater pain reduction (−5.5 vs −2.0, $P = .03$). All patients surpassed minimal clinical benefit thresholds of total joint arthroplasty (TJA) (Hip Disability and Osteoarthritis Score Junior 30.5 vs 20.8, $P = .23$; Knee Injury and Osteoarthritis Outcome Score Junior 23.3 vs 18.2, $P = .77$) within 6 weeks. Patients who objectively "take it easy" after TJA may experience less pain with no difference in early subjective outcome. Remote, passive analysis of outpatient wearable sensor data may permit real-time detection of early problems after TJA.

Introduction

Impaired physical activity early after total joint arthroplasty (TJA) may signal complications and patient dissatisfaction [1,2]. Traditional activity measures, such as timed walk tests or patient-reported questionnaires, require active administration and capture a single time point [3]. Commercially available wearable activity sensors—which are feasible for passively tracking patient activity, such as step counts, distance walked, and caloric measures of exercise intensity in TJA—might also be useful for detecting early postoperative problems after TJA [4,5]. We sought to determine if a consumer-wearable sensor can stratify patients by change in "activity" before and after total hip arthroplasty and total knee arthroplasty, which would identify slower-recovering patients who may benefit from therapeutic assistance.

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

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* Corresponding author. Department of Orthopaedic Surgery, University of California San Francisco, 500 Parnassus Ave, MU320W, San Francisco, CA 94143, USA. Tel.: +1 415 476 3900.
E-mail address: jtpatt@gmail.com

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Table 1
Patient characteristics by activity before and after total joint arthroplasty.

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/m^2)	29.9	[23.4-32.4]	25.8	[24.1-28.1]	.541

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

after surgery. Outcomes between activity clusters were then compared using χ^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 identified distinct patient groups of minimally changed (n = 15) and decreased (n = 5) activity after TJA. Activity groups were not significantly different by age, sex, procedure, BMI, ASA score [Table 1], or baseline HOOS Jr, KOOS Jr, and VR-12 scores [Table 2]. Activity groups were significantly different by change in daily step counts, miles walked, calories expended, and sedentary time [Table 2]. At 6 weeks after TJA, the decreased activity group reported greater and clinically relevant pain reduction (−5.5 vs −2.0, $P = .03$) with no differences in HOOS JR (30.5 vs 20.8, $P = .23$) or KOOS Jr (23.3 vs 18.2, $P = .77$) scores.

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 [6]. 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 2
Objective activity and patient reported measures by patient clusters of activity before and after total joint arthroplasty.

Activity or patient reported measure	Minimally changed activity		Decreased activity		*P*-value
	n = 15	IQR	n = 5	n = 15	
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	[−79.0 to 94.8]	-321.1	−[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 2.0]	-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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