Case Report

Objective monitoring of activity and Gait Velocity using wearable accelerometer following lumbar microdiscectomy to detect recurrent disc herniation

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Abstract: We report a case of a 39-year-old male with sciatica who underwent an L5/S1 microdiscectomy with objective physical activity measurements performed preoperatively and continually postoperatively up to 3-month using wireless accelerometer technology linked to the surgical practice; collecting distance travelled, daily step count (DSC) and Gait Velocity (GV). Preoperative, the patient was walking with a GV of 0.97 m/s and a DSC of less than 2,500. After the first month following surgery, the patient had increased mobility, with a GV of 1.58 m/s, and taking an average of over 4,500 steps per day. At day 57 postop, the patient experienced a recurrence of pain with reduction of GV, DSC and walking distance. Magnetic resonance imaging (MRI) was performed and revealed a recurrent disc herniation with further surgery on day 63, with a rapid return of function post 2nd surgery. The use of wireless accelerometers is practical in obtaining objective physical activity measurements before and after lumbar microdiscectomy, and will assist the surgeon and rehabilitation provider to monitor outcomes, complications and assist in clinical decision making.

Keywords: Accelerometer; Gait Velocity (GV); physical activity; objective measurement; microdiscectomy; recurrent disc herniation

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Introduction

Surgical management of spinal pathologies have been associated with substantial resource management and cost (1,2). Therefore, efficient monitoring and evaluation of pre- and post-surgical outcome is imperative for the patient, healthcare provider and also from a community perspective (3). Monitoring of surgical technique effectiveness, discharge disposition and functional outcome of patients are essential for efficient delivery of care as well as facilitating identification of appropriate resource allocation (4). This increases the need for the use of objective measuring tools to monitor mobility and post intervention recovery of patients (5).

Traditionally, quantification and comparison of recovery or outcomes in patient's post-spinal procedures used subjective rating scores such as Oswestry Disability Index (ODI), Visual Analogue pain Scale scores (VAS), Short Form Health (SF-12, SF-36) survey scores amongst a variety of others (6-8). However, the major problem in utilizing these scores is their subjectivity and the inherent bias with self-appraisal, as different individuals perceive and tolerate pain differently (9). Recent literature states that the ODI should not be a stand-alone tool for evaluating walking limitation in patients with lumbar spinal stenosis (10). For comprehensive assessment of walking ability, an objective walking test should be utilized in order to assess walking capacity. Wearable technologies such as accelerometers should be incorporated as a standardized tool for measuring

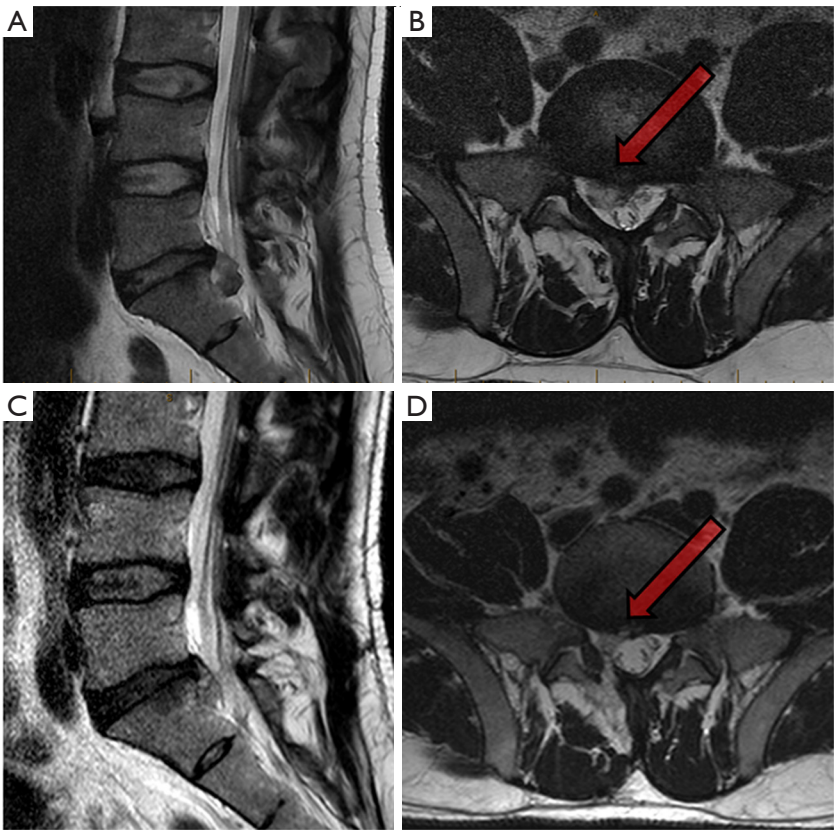


Figure 1 (A,B) (T2WI) sagittal and axial. Initial presentation with right S1 radiculopathy; (C,D) recurrent disc herniation through some annual defect as initial herniation. Pathological lesion (herniation) indicated (red arrow).

walking performance; used in conjunction with the walking test (10,11).

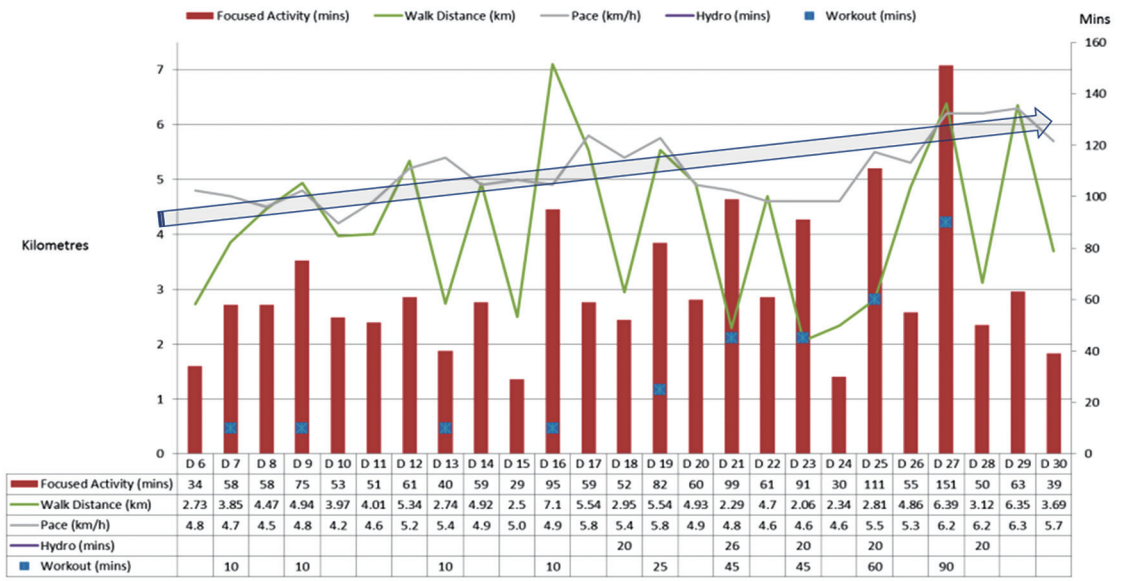
There have been multiple case studies on the effectiveness of wearable accelerometers post spinal surgery, for instance recovery post minimally invasive fusion (9). The first clinical series using accelerometers for monitoring post spinal surgery recovery was published in 2016 (12). With the recent advancement in medical wearables/wireless accelerometers, we have the capability to monitor and track, in real time, up-to-date patient's functional mobility including step counts and daily walking/running distance (13). The benefit of such technology is the ability to provide a continuous objective measure of the patient's daily activity to the surgeon, or health care practitioner. This data stream can be used as a measure of the extent of recovery and ambulatory function. Coupled with the follow-up reports of subjective measures (such as pain and disability scores), an improved understanding of a patient's progress can be achieved.

This case report explores the use of wireless accelerometer technology in a patient that had a lumbar microdiscectomy, with objective mobility and functional outcomes measured [distance travelled and Gait Velocity (GV)] both preoperatively and up to 3-month postoperatively.

Case presentation

A 39-year-old male presented with sciatica over a period of 6 months. His symptoms had a negative effect on quality of life, both personal and work-related. His medical history was unremarkable. MRI revealed a large volume L5/S1 disc herniation (*Figure 1A,B*), with no improvement with prolonged conservative care; a lumbar microdiscectomy was recommended.

The patients' distance travelled (kms), daily step count (DSC) and GV were monitored for 1-week pre-operative, and subsequently over 3-month post operation using an Apple Watch (Apple, San Francisco, CA, USA). Accelerometers are common tools used for quantification of physical activity, free from the bias of traditional subjective



	D 6	D 7	D 8	D 9	D 10	D 11	D 12	D 13	D 14	D 15	D 16	D 17	D 18	D 19	D 20	D 21	D 22	D 23	D 24	D 25	D 26	D 27	D 28	D 29	D 30
Focused Activity (mins)	34	58	58	75	53	51	61	40	59	29	95	59	52	82	60	99	61	91	30	111	55	151	50	63	39
Walk Distance (km)	2.73	3.85	4.47	4.94	3.97	4.01	5.34	2.74	4.92	2.5	7.1	5.54	2.95	5.54	4.93	2.29	4.7	2.06	2.34	2.81	4.86	6.39	3.12	6.35	3.69
Pace (km/h)	4.8	4.7	4.5	4.8	4.2	4.6	5.2	5.4	4.9	5.0	4.9	5.8	5.4	5.8	4.9	4.8	4.6	4.6	4.6	5.5	5.3	6.2	6.2	6.3	5.7
Hydro (mins)													20			26		20		20			20		
Workout (mins)		10		10				10			10			25		45		45		60		90			

Figure 2 Day 6–30 post microdiscectomy. Progressive increase in Gait Velocity (grey arrow) and distance travelled over initial month post-surgery.

measuring methods. The Apple Watch monitored and tracked the DSC, focused activity (minutes), estimated caloric expenditure, distance travelled and GV. The advantage is that individual patient parameters can be adjusted according to user age, weight, sex and height. The Apple Watch was worn during all waking hours.

An L5/S1 microdiscectomy was performed with no perioperative complications experienced. The patient was discharged within 24 hours, and returned to his accounting occupation and light duties after 2 weeks. Accelerometer data in the week prior to the operation showed the patient averaging a DSC of less than 2,500, over a daily distance of less than 1.6 km, with a GV of 0.97 m/s. In the first postoperative week, the patient's mobility was slightly improved, with a daily distance over 3 km, with a slight increase in GV over 1.0 m/s. By the second postoperative week, the parameters had improved well beyond baseline levels, continuing to increase in the subsequent weeks (*Figures 2,3*). At 1-month follow-up, the patient averaged over 4,500 DSC, for a distance of 3.8 km, and a GV of 1.58 m/s; a 60% improvement in both steps taken and GV in comparison to pre-operation numbers (*Figure 3*).

From the results yielded, there was a considerable improvement in all subjective measurements (VAS back and leg pain scores, ODI and SF-12) observed at 1-month follow-up compared to baseline scores; with VAS leg pain reduced from 8 to 2, and ODI reduced from 46 to 8. Thus, an intrinsic correlation between changes in ODI score and physical improvement at follow-up was quantified by accelerometer data.

On day 57, accelerometer data recorded an acute deterioration in DV and activity levels, correlating with the patient experiencing a recurrence of pain. Based on subjective information as well as the objective findings of gait deterioration, an MRI scan was organized (*Figure 1C,D*) which demonstrated a recurrent disc herniation. Redo surgery was performed on day 62 using a tubular retractor system, once more, with no perioperative complications. In the following days, the patient experienced rapid functional restoration and return to his continued progression prior to the recurrent episode in regards to the objective parameters of DSC, distance travelled and GV.

Discussion

Although there is a rising number of pilot studies reporting the use of accelerometers for evaluating function and recovery following a medical intervention (14-16), there have been limited studies in which medical wearables have been utilized within the scope of spine surgery. With regards to this case, postoperative objective accelerometer measurements demonstrated improvements

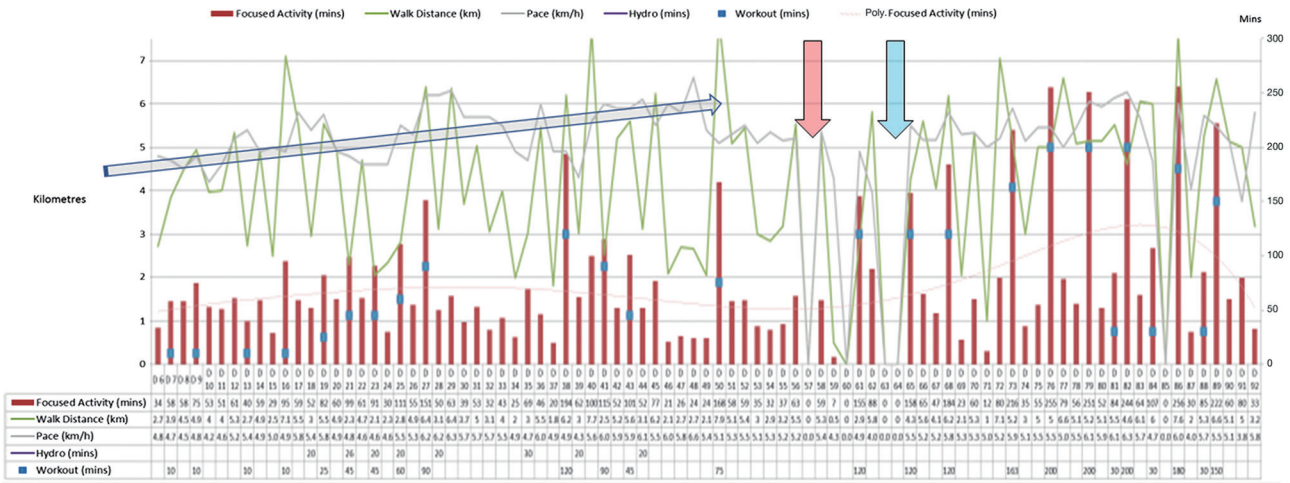


Figure 3 Day 6–92 following initial recovery over the first month (grey arrow), the patient experienced some mild low back pain symptoms commencing day 50, with a recurrence of severe leg pain on day 57 (red arrow). Redo microdiscectomy was performed in day 63 (blue arrow).

of 60% in distance walked per day, number of steps taken and GV at 1-month follow-up, compared to pre-operative measures. The sudden drop in functional status at day 57 was prominent, thus verifying the value of objective measurements with assistance in identifying the postoperative complication, such as recurrent disc herniation, a common yet undesirable outcome of microdiscectomy (17,18).

As discussed, functional recovery post spinal procedures is currently reported via proxy parameters such as quality of life, pain and functional scores (VAS, ODI, SF12/SF36, Roland Morris disability index), and duration of hospital stay (8). However, subjective measures alone are strongly influenced by inherent bias and individual variation. As patients have different expectations of pain and functional tolerance, these subjective measurements inevitably result in a lack of standardization of outcomes evaluation across different surgical procedures (19,20). Compensation, psychological influences and litigious activity which may or may not be associated with their surgical interventions can confer potentially signification variances of self-reported measures of quality of life scores (21).

Advances in medical wearables including accelerometers, gyroscopes and global positioning systems (GPS), have led to the dawn of real-time recording, reporting and assessing objective patient recovery, free of subjectivity. Our report is an example of the benefits of wireless technology in assessing the outcome of microdiscectomy surgery, with real-time reporting to the health care professional, with rapid identification of the relevant complication of recurrent disc herniation.

The use of GV as an instrument for objective measurement has long been deliberated in the literature (22), with evidence leading to the conclusion that it serves as an accurate indicator of a patient's level of physical mobility and general health status. Step count has been investigated for its use (23) in the clinical setting, and has led to the result that with an average of at least 4,300 steps per day, this translates to one less day in hospital per 3 years of life; giving credibility to its association with musculoskeletal conditions. Objective gait parameters serve the purpose to convert the observation of impaired mobility, into an objective 'scorable' context. This leads into avenues of utilizing these instruments as a potent screening tool to allow for efficient identification and treatment of musculoskeletal and neurological injury/disease in patients, as shown by this case report, by the use of simple wearable technologies.

In the time period before the recurrence on day 57, all three objective measurements (DSC, GV, Activity) show constant improvement and thus reflect a positive post-operative outcome. At the return of pain and the short period thereafter, a depression in the all three indicators is noted which subsequently facilitated the MRI scan, and diagnosis of recurrent disc herniation. This diagnosis may not have been made as efficiently if it were not for the measurement of gait velocity, step distance and count as objective tools

used in the monitoring of this patient pre- and post-operation; potentially evading further consequence.

The data obtained from the accelerometer showed a strong improvement in GV, distance travelled and steps taken; all within the first month post-surgery. Self-reported scores such as ODI were taken at the standard time points of 6 weeks and 3 months, however they were not predictive of deterioration in function as seen in this patient. A continuous stream of objective information via the wearable accelerometer proved to be essential in the early detection of complications, and efficient delivery of appropriate follow on care.

Conclusions

As demonstrated in this case, the use of a continuous objective measuring tool is invaluable particularly in detecting sudden change or deterioration of function. Until 12 months post-operation the patient continued to wear the Apple Watch with no further issues and maintained a GV of over 1.5 m/s. Self-reported subjective index scores were not used for long-term follow-up. As a result of this case study, we recommend the use of accelerometers for quantifying physical activity post spine surgery as a feasible outcomes measurement tool. Combined with subjective measurements, wearable devices that monitor objective outcomes provide substantial benefit in tracking patient progress. Further advancement or improvements of objective measurements may eventually replace the current subjective measurement tools, and the elimination of bias; however, their use and benefits should be validated in larger prospective studies.

Acknowledgements

None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: This study was approved by the South Eastern Local Health District Human Research Ethics Committee, with the reference number 17/184. Written informed consent was obtained from the patient for publication of this manuscript and any accompanying images.

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