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Review

Accelerometers for objective evaluation of physical activity following spine surgery

Prashanth J. Rao [a,b,c,d], Kevin Phan [a,b,c,d], Monish M. Maharaj [a,b,c], Matthew H. Pelletier [e], William R. Walsh [e], Ralph J. Mobbs [a,b,c,*]

[a] NeuroSpine Surgery Research Group (NSURG), Sydney, NSW, Australia
[b] NeuroSpine Clinic, Prince of Wales Private Hospital, Suite 7, Level 7, Randwick, Sydney, NSW 2031, Australia
[c] University of New South Wales (UNSW) Australia, Sydney, NSW, Australia
[d] Westmead Hospital, University of Sydney, Sydney, NSW, Australia
[e] Surgical & Orthopaedic Research Laboratories, Prince of Wales Clinical School, Prince of Wales Hospital, Sydney, NSW, Australia

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ABSTRACT

With the potential of bias from subjective evaluation scores in spine surgery, there is a need for practical and accurate quantitative methods of analysing patient recovery. In recent years, technologies such as accelerometers and global positioning systems have been introduced as potential objective measures for pain and symptoms following spine surgery. Overall, this perspective article aims to discuss and critique currently utilised methods of monitoring spine surgical outcomes. After analysing current modalities it will briefly analyse new potential methods before examining the place for accelerometers in the field of spine surgery. A literature review was performed on the use of accelerometers for objective evaluation of symptoms and disability after spine surgery, and perspectives are summarised in this article. Physical activity measurement with the use of accelerometers following spine surgery patients is practical and quantitative. The currently available accelerometers have the potential to transform the way functional outcomes from spine surgery are assessed. One key advantage is the collection of standardised objective measurements across studies. Future studies should aim to validate accelerometer data in relation to traditional measures of functional recovery, patient outcomes, and physical activity.

1. Introduction

Subjective, patient-based ratings of symptoms are often the key measure of success reported for patients undergoing spine surgery [1]. Commonly used subjective measures of perceived disability and health status include the 36-item Short Form Health surveys (SF-36), the Oswestry Disability Index (ODI), and the Visual Analogue Scale score (VAS), and these have been used to gauge the success and efficacy of spinal interventions [2]. A drawback of this method of assessment is the inherent bias from personal evaluation, where self-scores may change subject to multifactorial complex interactions between the patient, and their perception of their disability, symptoms and overall performance [3,4].

There is a need for practical and accurate quantitative methods of analysing patient recovery, particularly level of physical activity, to avoid bias from subjective evaluations [5]. Though there remains benefit in such methods towards understanding quality of life, the advantages of quantitative methods is a more objective understanding of recovery [6]. Current attempts at standardised quantitative methods applied in the spine surgery setting include measurements of radiograph angles, measuring the percentage of paralysis, and quantification of range of motion. However, these quantification approaches are not standardised, with different measurement and analysis techniques employed across different study groups. Furthermore, such measurements do not provide real-time estimates of mobility, gait, and frequency, or intensity and duration of physical activity. Nevertheless, a number of methods and trials have been undertaken over the last decade with varying results, though a practical and feasible method has yet to be accepted by medical professionals; particularly none taking advantage of technological evolution through biomechanical software and accelerometer motion tracking [7–9].

Overall, the aim of this article was to perform a literature review and discuss and critique currently utilised methods of

* Corresponding author. Tel.: +61 4 0196 5057; fax: +61 2 9650 4943.
E-mail address: ralphmobbs@hotmail.com (R.J. Mobbs).

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monitoring spine surgical outcomes [10]. After analysing well established modalities it will briefly analyse new potential methods before examining the place for accelerometers in the field of spine surgery. Accelerometers, particularly those which are widely available, affordable and have supporting software, have been shown to be of particular use. This article will analyse the feasibility of their use within the discipline of spine surgery outcomes.

2. Physical activity following spine surgery

The number of patients who present with spinal degeneration and structural changes in the lumbar spine is increasing [11,12]. In many of these patients, gradual structural changes have led to spinal canal stenosis and compression of nerve roots, and in other cases, degradation or malfunction of the intervertebral discs. These pathologies are often symptomatic, leading to neurogenic claudication in the form of lower limb pain, back pain, paraesthesia and cramping, and in some cases, impaired ambulation [13]. Surgical intervention is an option which may help alleviate or relieve patient symptoms when conservative treatment has failed.

Typically the outcomes of spine surgery are measured by subjective reports of physical activity and mental health scores (Table 1). In 1994, a retrospective analysis of 144 lumbar spinal surgery patients concluded that the absolute value and change in ODI scores after surgery was the optimal marker for outcomes following operation [14]. The ODI score is determined from questionnaires which assess factors including pain intensity, personal care, lifting, walking, sitting, standing, sleeping, and ambulation, based on a score from 0 (no difficulty) to 5 (maximum difficulty) [15]. Since then, the ODI has been one of the most commonly used subjective scores for low back pain disability in reports of spine surgery. In 2001, the VAS spine score was validated by a German group [16], demonstrating good reliability, high internal consistency and validity in a group of 53 patients undergoing thoracolumbar surgery. The VAS score involves a 15-item questionnaire about disability and pain intensity in patients with low back pain [17].

There have been a myriad of other evaluation systems developed since then and used, however, these score systems have lacked standardisation which limits their applicability. A recent systematic review [18] of the pain rating systems used to compare functional outcomes in patients with low back pain highlighted that each scoring system evaluated a different set of variables. Even when scores used the same variables, the scoring systems weighted the assessed variables differently. The interpretation of these scores becomes challenging given that they are measuring the totality of different outcomes. Many scores have not been formally validated, and their repeatability and sensitivity to change may be questionable. Several studies have investigated the validity of these subjective scores in the assessment of outcomes following spine surgery. In a recent study by Kuittinen et al. [19], visual assessment using VAS scores and subjective self-report ODI scores for pain were compared with quantitatively-assessed stenosis using lumbar MRI measures of minimal dural sac area, level by level. There was no correlation found between stenosis of the dural sac and patient symptoms on the functional scores applied. In another study by Sirvanci et al. [20], no correlation was found between ODI scores and MRI determined radiological stenosis. From these studies, it has been emphasised that the subjective nature and inherently different domains in each score may have introduced bias, reducing its validity in outcome or success measurement. Additionally, De Vine et al. [1] found none of the current chronic low back pain scores correlate with each other.

Given the limitations of subjective self-assessment scores, there has been a recent surge in the development of objective measurements for disability and symptoms. In recent years the significant propagation of wireless technology, accelerometers [21] and global positioning systems [22] has brought the capabilities for objective quantification to the general population. Accelerometers bring the promise of retrieving real-time patient data on relevant parameters including mobility, gait, and frequency, intensity and duration of physical activity [8]. Some advantages garnered with the use of this technology include the convenience of generating remote, real-time data from subjects, traversing issues of bias with self-reports, changes in subjective perceptions of pain with repeated questionnaires or tests on follow-up, and the potential for medical intervention or modification of treatment course as required, regardless of scheduled follow-up visits, to improve patient care and outcomes.

Table 1
Quantitative pain scoring tools employed in spinal surgery and rehabilitation

	Methodology
Objective	Acclerometry Laboratory kinematic analysis Actigraphy
Subjective	Oswestry Disability Index Medical Outcome Study Short Form-36 Rowland–Morris Disability Questionnaire McKenzie Method American Academy of Orthopaedics Score North American Spine Society Score Japanese Orthopaedic Association Score* Visual Analogue Score*

* Modified scales based on these original tools are employed.

3. Currently employed measurement methods

Questions remain surrounding the accuracy of qualitative scales as a means of recording rehabilitation progress. In a recent cross-sectional study by Pryce et al. [3], self-reported pain ODI scores and SF-36 scores were collected from 33 patients with lumbar spine stenosis. Real-time ambulatory data was also collected using accelerometer technology. This study concluded that subjective measures of pain and disability had a limited correlation and limited ability to account for real-life performance of patients with lumbar spine stenosis. While this study is preliminary and requires further validation, there is evidence to demonstrate that traditional subjective functional measurements of pain had a limited ability to predict real-time physical activity independent of pain. The paucity of available literature thus far calls for further validation studies, including investigations comparing and correlating physical activity measures by accelerometers with subjective measures of pain and disability. Outcomes of such studies will clarify the role and place of objective functional measurements *versus* subjective pain and disability scores when assessing follow-up of spinal surgical procedures and rehabilitation progress.

A study carried out by Troiano et al. [23] in the USA on a nationally representative group comparing accelerometer data on physical activity was consistent with findings based on self-reports for age and sex. Males were proven to be physically more active than females, while activity was lower in successive age groups. Accelerometer data provides a new picture of physical activity through results in absolute count, duration and adherence. Furthermore with further analysis the study concluded that self-report qualitative data was subject to bias and overestimations in interpreting sedentary or light activity as moderate or high activity. This bias in self-reports could lead to erroneous conclusions in interventions and epidemiological trials. The accelerometer on the other hand has definite cut-offs for activity levels and hence provided a reliable method of classification. However, it must be noted that different accelerometers use different software