Physiotherapy Management of Patients Prior to and Immediately After Lumbar Spinal Surgery

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List of Abbreviations

15D	15-D Instrument
ANZCTR	Australian New Zealand Clinical Trails Registry
BMI	Body Mass Index
BPI	Brief Pain Inventory
CI	Confidence Interval
CL	Crook-lie
D1	First post-operative day
D2	Second pot-operative day
D3	Third post-operative day
DF	Dorsiflexion
DOS	Day of Surgery
EVP	Events per Predictor Variable
Ext	Extension
Flex	Flexion
FU	Follow-up
GAD-7	Generalised Anxiety Disorder 7 Item Scale
GPE	Global Perceived Effect
HEP	Home Exercise Program
HRQOL	Health Related Quality of Life
ICC	Intraclass Correlation Coefficient
IPAQ-SF	International Physical Activity Questionnaire Short Form
IRQ	Inner Range Quartile
LL	Lower Limb
MCID	Minimum Clinically Important Difference
MET	Metabolic Equivalent
Mins	Minutes
MPQ	McGill Pain Questionnaire
Mths	Months
N/A	Not applicable
NPRS	Numerical Pain Rating Scale
NSD	No Significant Difference
ODI	Oswestry Disability Index

ODQ	Oswestry Disability Questionnaire
OM	Outcome Measure
OP	Outpatient
OR	Odds Ratio
PEDro	Physiotherapy Evidence Database
PCA	Patient Controlled Analgesia
PF	Plantar Flexion
PHQ-9	Patient Health Questionnaire Depression Scale
PSD	Percentage of Steps Detected
QPBDS	Quebec Back Pain Disability Questionnaire
RCT	Randomised Controlled Trial
ROM	Range of Motion
RMQ	Roland Morris Questionnaire
RTW	Return to Work
SCB	Substantial Clinical Benefit
SD	Standard Deviation
SEM	Standard Error of Measurement
SF-36 (PCS)	Short Form 36 (Physical Component Summary)
SF-MPQ	Short Form McGill Pain Questionnaire
SL	Side-lie
SLR	Straight leg raise
St	Stand
STS	Sit to stand
SVPHF	St Vincent's Private Hospital Fitzroy
SVPHM	St Vincent's Private Hospital Melbourne
TA	Transverse Abdominus
TUG	Timed Up and Go
VAS	Visual Analogue Scale

Summary

This thesis explores the physiotherapy management of patients before, and early after lumbar spinal surgery. The first two studies describe the evidence for physiotherapy intervention, and the current peri-operative physiotherapy management of patients undergoing lumbar surgery in Australian hospitals. The second component of this thesis describes the physical activity patterns of patients in the first post-operative week, and investigates the relationship between the time spent walking over this period and recovery of physical function six months after surgery.

A systematic review of the evidence for physiotherapy before and immediately after lumbar surgery found that there was limited evidence to guide physiotherapy practice. Following on from the systematic review, an Australian wide survey was conducted to establish current physiotherapy practice in this patient population. This survey found that the majority of patients undergoing lumbar surgery were seen by a physiotherapist during their hospital admission. While there was considerable variation in the specific physiotherapy interventions provided, increasing walking from early after surgery was a consistent goal of treatment across all hospitals. However, despite this focus on increasing walking, it is unknown whether more walking is associated with improved post-operative outcomes.

To further investigate the relationship between the amount of walking after lumbar surgery and longer-term recovery, a valid means of quantifying walking in this patient group was required. A study was conducted to determine whether the ActivPAL3©, Fitbit Flex© and Jawbone Up Move© accelerometers provide a valid measure of step count in patients early after lumbar fusion surgery. This study determined that the ActivPAL3© provides a valid measure of step count, however neither the Fitbit© nor the Jawbone© measured step count with sufficient accuracy in this patient population.

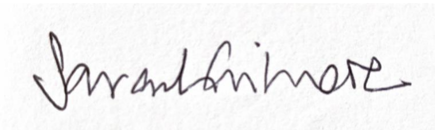
The activity patterns of patients in the first week after lumbar surgery was investigated using the ActivPAL3© accelerometer. This study demonstrated that while walking time progressively increased over the first post-operative week, patients spent an average of only three percent of their time walking. This study also found that a low step count in the first week after surgery was associated with a number of patient factors including a longer duration of pre-operative pain, more severe pre-operative pain, undergoing a fusion procedure, and the presence of post-operative complications such as dizziness and nausea. On examination of the relationship between walking and patient discharge outcomes, a lower step count was associated with a longer hospital stay and an increased likelihood of discharge to a rehabilitation facility.

The final study of this thesis was conducted to determine whether the time spent walking in the first post-operative week was associated with longer term improvement in physical function or pain. This study found that greater walking time in the immediate post-operative period was predictive of substantial improvement in physical function six months after surgery. In addition to walking time, experiencing pre-operative pain for less than 12 months, having low pre-operative physical function, and being younger than 65 years old were also predictive of substantial improvement in physical function at six months.

This thesis identified that increased walking time early after lumbar surgery is associated with both improved short-term discharge outcomes and greater longer-term functional recovery. These findings form the basis from which ongoing research may be designed, to investigate whether physiotherapy intervention aiming to increase post-operative walking leads to an improvement in patient outcome.

Statement of Authorship

This thesis includes work by the author that has been published as described in the text. Except where reference is made in the text of this thesis, this thesis contains no other material published elsewhere or extracted in whole or in part from a thesis accepted for the award of any other degree or diploma. No other person's work has been used without due acknowledgment in the main text of the thesis. This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution.

Signature: 

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Publications and Presentations Arising from this Thesis

Publications

Gilmore SJ, McClelland JA, Davidson M. (2014). Physiotheraputic interventions before and after surgery for degenerative lumbar conditions: a systematic review. *Physiotherapy* 101(2):111-8

Gilmore SJ, McClelland JA, Davidson M. (2016). Physiotherapy management of patients undergoing lumbar spinal surgery for degenerative conditions: a survey of Australian physiotherapists. *New Zealand Journal of Physiotherapy* 44(2):105-12

Gilmore SJ, McClelland JA, Davidson M. (2016). Does walking after lumbar spinal surgery predict recovery of function at six months? Protocol for a prospective cohort study. *BMC Musculoskeletal Disorders* 17(1):472-8

Gilmore SJ, Davidson M, Hahne AJ, McClelland JA. (2018). The validity of using activity monitors to detect step count after lumbar fusion surgery. *Disability and Rehabilitation* 16:1-6

Gilmore SJ, Hahne AJ, Davidson M, McClelland JA. (2019). Physical activity patterns of patients immediately after lumbar surgery. *Disability and Rehabilitation* 15:1-7

Gilmore SJ, Hahne AJ, Davidson M, McClelland JA. (2019). Predictors of substantial improvement in physical function six months after lumbar surgery: is early post-operative walking important? A prospective cohort study. *BMC Musculoskeletal Disorders* 20(1):418-26

Conference Presentations

Physiotherapy management of patients undergoing lumbar spinal surgery for degenerative conditions: a survey of Australian physiotherapists. NSW ACI Neurosurgical Education Day, Sydney, September 2015.

How much walking do patients do after lumbar spinal surgery? iCAHE Conference, Adelaide, November 2017 (Prize: best student presentation).

Monitoring activity in the acute inpatient setting: How accurate are activity monitors? Victorian Allied Health Conference, Melbourne, April 2017.

Physical activity patterns of patients immediately after lumbar spinal surgery (poster presentation). Spine Society of Australia, 29th Annual Scientific Meeting, Adelaide, April 2018.

Early walking after lumbar spinal surgery as a predictor of outcome (podium presentation). Spine Society of Australia, 29th Annual Scientific Meeting, Adelaide, April 2018.

Chapter 1: Introduction

Low back pain is the leading cause of disability worldwide, with an estimated 9.4% of the global population experiencing low back pain at any one time (Hoy et al., 2014; Vos et al., 2017). An episode of low back pain can have a considerable impact on quality of life, with a cost to both the individual and society through an inability to undertake usual family and work responsibilities, and participate in community activities (Froud et al., 2014).

In Australasia, the point prevalence of low back pain is even higher than the global average, at 12.9% for men, and 11.5% for women (Australian Institute of Health and Welfare, 2013; Hoy et al., 2014). In addition, low back pain is the leading cause of disability, and the leading cause of overall burden on society due to disability (Hoy et al., 2014). The years lived with disability increased in Australia by 18% between 2006 and 2016, and disease burden of low back pain rose 45% between 1990 and 2010 (Vos et al., 2017). As the prevalence of low back pain peaks around the age of 80 years (Hoy et al, 2014), it is likely that the aging population has contributed to this increase, and that both low back pain related disability and the associated burden will continue to increase into the future (Hoy et al., 2014).

1.1. Lumbar surgery

Alongside the rising incidence of back pain, the number of spinal surgeries performed for the management of low back pathology and associated radiculopathy has increased considerably over the last two decades. The number of spinal fusion procedures performed in Australia increased by 175% (8.4 per 100,000 to 23.1 per 100,000) between 1997 and 2006, with the majority of the increase being in the private sector (Harris and Dao, 2009). A similar pattern has also been observed in the United States, with the number of spinal fusion procedures increasing by 137% between 1998 and 2008 (Rajaee et al., 2012). The same study reported a 3.3-fold increase in the total hospital charges associated with spinal fusion surgery, and a 7.9-fold increase in the national bill for spinal fusion surgery over the decade ending 2008 (Rajaee et al., 2012). While a proportion of this observed growth may be attributed to increasing rates of back pain, the number of surgical procedures performed and the associated costs have grown at a disproportionately faster rate than the incidence of back pain within the community.

This disproportionate increase in the number of surgeries and the associated costs has led to increased scrutiny from national regulatory and funding bodies (Australian Commission on Safety and Quality in Healthcare, 2017). As a result, there is a demand for high quality research to guide best practice management of low back pain, specifically in relation to surgical intervention.

It is generally accepted that surgical intervention for the management of non-specific back pain with no radicular symptoms, which makes up approximately 90% of all back-pain presentations (Haldeman et al., 2012), has no clinical benefit over conservative management (Oliveira et al., 2018). In April 2018, the Australian national health care funding scheme, Medicare, announced they would no longer fund spinal fusion for the management of uncomplicated axial lower back pain (Australian Government Department of Health, 2018), with similar funding restrictions observed in the UK (NHS England, 2013).

The evidence, however, is less conclusive for patients who present with radiculopathy, which makes up between five and nine percent of those that present with back pain/pathology (Haldeman et al., 2012). With appropriate patient selection, combined with well-designed peri-operative care, this group of patients may benefit from surgical intervention (Pearson et al., 2012). While there has been a growth in research investigating patient selection for surgery, very little is known about the role adjunct therapies such as physiotherapy intervention and rehabilitation services, have on optimising patient outcome (McGregor et al., 2013; Oosterhuis et al., 2014; Rushton et al., 2011). Having a strong evidence base to guide pre and post-operative rehabilitation care is necessary to further drive improvement in patient outcome, particularly with the increasing need for proof of benefit from regulatory and funding bodies.

1.2. Physiotherapy intervention before and after lumbar surgery

Physiotherapists are involved in the pre and post-operative rehabilitation of patients undergoing lumbar spinal surgery in more than 80% of UK hospitals (Rushton et al., 2014; Williamson et al., 2007). The overall goals of physiotherapy commonly include facilitating independent mobility, providing an exercise program, and providing advice and education regarding post-operative activity and restrictions. However, within these three broad categories the specific physiotherapy interventions provided are highly variable (Rushton et al., 2014; Williamson et al., 2007).

To date, there has been very little research conducted investigating the effectiveness of physiotherapy interventions commencing immediately after lumbar spinal surgery. A systematic review investigating whether rehabilitation improves patient outcome after lumbar disc surgery identified four studies in which intervention started in the early post-operative period (Oosterhuis et al., 2014), and in only two of these four studies did the intervention start during the inpatient hospital admission. All four studies included an exercise prescription component within the rehabilitation programs that were assessed, however there was considerable heterogeneity in the peri-operative care provided within both the intervention as well as the comparison groups (Ju et al., 2012; Kjeilby-Wendt et al., 1998; Newsome et al., 2009; Scrimshaw and Maher, 2001).

Three of the four included studies also demonstrated a high risk of bias. This review concluded, based on very low-quality evidence, that there is little benefit in commencing an exercise program immediately following surgery. Three further systematic reviews have investigated the effectiveness of rehabilitation following lumbar discectomy (Rushton et al., 2011), decompression with or without fusion (McGregor et al., 2013), and lumbar fusion (Rushton et al., 2012). McGregor et. al. (2013) concluded that active rehabilitation is more effective than usual care in improving short and long term function following lumbar decompression, while the other two reviews were inconclusive due to a small number of studies and limited comparability of outcome measures. However, this information is of limited value in the acute post-operative phase as these reviews only identified interventions conducted in the outpatient setting and were therefore unable to draw any conclusions regarding the effectiveness of physiotherapy intervention commencing immediately after surgery.

Current evidence indicates that the majority of patients undergoing lumbar surgery are seen by a physiotherapist during their hospital admission (Rushton et al., 2014; Williamson et al., 2007). Given the increasing number of spinal surgeries being performed, this potentially represents a considerable investment of resources in a clinical setting where it remains unclear whether physiotherapy intervention is effective in improving either short or long term outcomes.

To determine whether further research into the effectiveness of physiotherapy intervention in the acute hospital inpatient setting is indicated, a review of the current evidence specific to this setting is required. In addition, there is a need to determine whether the clinical practice trends observed by Rushton et al., (2014) and Williamson et al., (2007) are consistent with clinical practice outside of the UK. The first section of this thesis (Chapters 2 and 3) address these two topics, while the remainder of this thesis explores research themes that emerge from these two preliminary studies.

1.3. Research aims and overview

This thesis is comprised of two sections. The first section aimed to explore current physiotherapy practice before and immediately after lumbar spinal surgery, as introduced in Chapter 1 and presented in Chapters 2 and 3. The second section of this thesis was informed by the findings presented in Chapters 2 and 3, and is introduced in Chapter 4. This section aimed to explore the relationship between early physical activity after lumbar surgery (in this case walking), and longer-term recovery.

The specific aims addressed in this thesis were:

1. To systematically review the existing evidence investigating the effect of physiotherapy interventions before and immediately after lumbar spinal surgery.
2. To describe current peri-operative physiotherapy management of adults undergoing lumbar spinal surgery in Australia.
3. To evaluate the validity of the ActivPAL3©, Fitbit Flex© and Jawbone Up Move© activity monitors when measuring step count in patients early after lumbar fusion surgery.
4. To describe the physical activity patterns of patients in the first week after lumbar spinal surgery, and to investigate whether participant characteristics, surgical factors, or post-operative pain and function may explain variation in activity over this time period.
5. To establish the relationship between time spent walking in the first week after lumbar surgery and recovery of pain and physical function at six months.

This thesis is comprised of a series of publications that address the research aims outlined above. They are presented in sequential order and can be read independently of each other. Chapters 2, 3, 4, 5, 6 and 7 have been published in peer-reviewed journals and are presented in their published format.

The first two studies (Chapters 2 and 3) provide background information regarding current evidence for, and a summary of the routine physiotherapy management of patients undergoing lumbar surgery. Chapter 2 presents a systematic review of physiotherapy intervention before and immediately after surgery for degenerative lumbar conditions (Aim 1); Chapter 3 describes a survey of physiotherapy management of patients undergoing lumbar spinal surgery in Australian hospitals (Aim 2). This background information was then used to inform the aims and design for the subsequent studies, as introduced in Chapter 4.

The study presented in Chapter 4 evaluated the validity of three accelerometers for measuring step count and walking time in this patient population, one designed primarily for use in the research setting and two commercially available monitors (Aim 3, Chapter 4). A valid measure of step count and walking time was required for the subsequent studies.

Chapter 5 presents the published research protocol designed to investigate physical activity following lumbar surgery, and the relationship between physical activity and longer-term recovery. This protocol describes the studies presented in Chapters 6 and 7, which address Aims 4 and 5.

Chapter 6 describes outcomes from an observational study evaluating the physical activity patterns of patients in the first week after lumbar spinal surgery (Aim 4). This study also investigated the association between step count and factors that potentially limit walking, such as pre-operative participant characteristics, surgical procedure, and post-operative pain (Aim 4). The final study of this thesis is described in Chapter 7. This study investigated whether the time spent walking in the first week after lumbar surgery predicted recovery of physical function at six months (Aim 5).

The final chapter (Chapter 8) provides an overall discussion of the research presented in this thesis, including the impact on physiotherapy practice in the clinical setting, and direction for ongoing research in this field.

Chapter 2: Physiotherapeutic interventions before and after surgery for degenerative lumbar conditions: a systematic review

While physiotherapists are routinely involved in patient care immediately after lumbar spinal surgery (Rushton et al., 2014; Williamson et al., 2007), little is known about whether post-operative physiotherapy intervention improves patient outcome. Four previous systematic reviews have evaluated rehabilitation interventions in this population. However, due to either no identified studies (McGregor et al., 2013), a small number of identified studies (Oosterhuis et al., 2014) or the study inclusion criteria being limited to the outpatient setting (Rushton et al., 2012; Rushton et al., 2011), no conclusions have been drawn regarding the effectiveness of physiotherapy intervention specific to the immediate post-operative period. A systematic review of the literature was therefore conducted to quantify and evaluate the effectiveness of physiotherapy intervention prior to and immediately after lumbar surgery for degenerative conditions.

The systematic review is presented as the manuscript accepted for publication in *Physiotherapy*, ©2014. This manuscript version is made available under the CC-BY-NC-ND 4.0 licence http://creativecommons.org/licences/by-nc-nd/4.0/. The published article can be accessed via: https://www.physiotherapyjournal.com/article /S0031-9406(14)00081-9/fulltext; Gilmore SJ, McClelland JA, Davidson M. (2014). Physiotheraputic interventions before and after surgery for degenerative lumbar conditions: a systematic review. *Physiotherapy* 101(2):111-8

The full list of search terms (as referred to in the Search Methods section of the published article) is included as an appendix (Appendix III), along with the figures and tables referred to in the text (Appendix IV).

Physiotherapeutic interventions before and after surgery for degenerative lumbar conditions: a systematic review

Abstract

Background

Physiotherapy management of patients immediately following lumbar spinal surgery is common, however there is considerable variability in the interventions provided.

Objectives

To assess the effect of peri-operative physiotherapy intervention in adults undergoing surgery for the management of degenerative lumbar conditions.

Data sources

The Cochrane Library, Medline, Embase, CINAHL and PEDro were searched from inception to August 2012.

Study selection

Randomised controlled trials investigating physiotherapy interventions prior to and immediately following surgery for degenerative lumbar conditions were included.

Data extraction and synthesis

Two reviewers independently extracted data using a standardised form. Risk of bias was assessed using a modified version of the Cochrane Collaboration tool. The quality of evidence was assessed using the GRADE approach and the treatment effect size was calculated where comparable outcome measures were used across multiple trials.

Results

Four studies were included. There is very low-quality evidence that pre and post-operative exercise in addition to standard physiotherapy care may reduce pain, time taken to achieve post-operative functional milestones, and post-operative time off work. Results from one study indicate there is no clear benefit or risk of harm from performing either prone or side-lying transfers.

Conclusion and implications of key findings

Very low-quality evidence suggests physiotherapy may improve pain and function following lumbar surgery. Due to low numbers of included studies and variation in interventions assessed the current evidence provides limited guidance for physiotherapy practice. Further research is required to determine the effectiveness of physiotherapy intervention in this population.

Introduction

Low back pain is the most common cause of disability globally [1]. In Australia, up to 80% of people experience low back pain over a lifetime [2], with approximately 14% experiencing pain for six months or longer [3]. Where conservative management of degenerative lumbar conditions including lumbar disc disease, spinal stenosis, and spondylolysthesis is not successful in managing pain and reducing disability, surgery may be recommended. The rate of spinal fusion surgery carried out in Australia increased by 175% between 1997 and 2006 [4]. A similar increase of 111% was demonstrated in the United States between 1998 and 2008, with an associated 3.3 fold increase in total hospital charges and a 7.9 fold increase in total expenses [5].

In the inpatient setting, physiotherapy intervention following lumbar surgery is aimed at both facilitating a safe discharge from hospital and promoting post-operative functional recovery. A survey of UK physiotherapists working with patients following lumbar disc surgery [6] found that the majority of patients received post-operative physiotherapy that commenced the day after surgery. There was considerable variability in the interventions provided, with five main themes of treatment identified - mobilising patients, spinal range of motion exercises, stability exercises, neural mobility exercises, and advice and education. This variability in post-operative management of spinal patients has also been demonstrated amongst UK spinal surgeons, with inconsistencies in patient mobilisation, restrictions, advice and rehabilitation [7]. Williamson et al [6] reported that the most common component of physiotherapy intervention was to mobilise patients to ensure a safe discharge. While this survey was targeted at physiotherapy management following lumbar disc surgery, it would be expected that physiotherapy intervention following surgery for the management of degenerative lumbar spinal stenosis and spondylolysthesis would have a similar focus of achieving functional goals to ensure a safe discharge.

There is a lack of published information regarding the standard provision of physiotherapy prior to lumbar surgery. There is evidence that physiotherapy intervention in the form of exercise, advice and education occurs prior to joint replacement surgery [8], cardiac surgery [9] and thoracic surgery [10] and it is likely that in many hospitals pre-operative physiotherapy forms part of routine care prior to lumbar surgery.

Variability in the provision of outpatient physiotherapy intervention following lumbar disc surgery has also been demonstrated, with less than half the centres surveyed routinely referring patients on to outpatient services [6]. As a result, intervention provided by the inpatient physiotherapist, including mobility and functional task training, exercise prescription, and advice and education may play a significant role in aiding patients return to work and normal activity, in turn reducing the financial impact of surgery and improving quality of life.

To date, there are no published systematic reviews evaluating the effects of physiotherapy management of patients undergoing lumbar surgery specific to the pre-operative or post-operative inpatient setting. A review of the evidence for physiotherapy management of spinal surgery patients is required to guide practice in the peri-operative inpatient setting. It is intended that this information will assist in the design of effective physiotherapy programmes, assist in the selection of patients who may benefit from a specific intervention, and identify interventions that may lead to adverse events. In the current environment of increasing budgetary and resourcing constraints, combined with the need for all health interventions to have a strong evidence base, this information will assist physiotherapists and health management to allocate resources to patient populations that will benefit the most.

Objectives

The aim of this review was to assess the effect of physiotherapy intervention in adults undergoing surgery for the management of degenerative lumbar conditions. The research questions underpinning this review are: Does peri-operative physiotherapy for patients undergoing lumbar spine surgery improve outcomes in the immediate post-operative period? And, what specific physiotherapy interventions have been studied? All interventions carried out by a physiotherapist both pre-operatively (where the intervention is directly relevant to the surgery), and post-operatively in the inpatient setting were considered.

Materials and Methods

This review included randomised controlled trials and pseudo (quasi) randomised controlled trials of patients who had undergone surgery for degenerative lumbar conditions and were aged 18 years and older. There were no restrictions on type or duration of pre-operative symptoms, or type of surgery. Trials that included surgery for the management of lumbar fractures, tumours, synovial cysts, and scoliosis/deformity correction were excluded.

Pre-operative interventions in the inpatient or outpatient setting were included where the intervention was directly relevant to the surgery. All interventions carried out by a physiotherapist post-operatively in the acute inpatient setting were included where:
The intervention was restricted to the inpatient setting only. Ongoing outcome measurement could occur in the outpatient or community setting, or
The intervention continued from the inpatient into the outpatient or community setting, but results from the inpatient phase could be independently analysed. Outcome measurement must have occurred either on discharge from hospital or prior to any outpatient or community input commencing.

Measures that assessed for change in pain and other symptoms, back specific and general functional status, and quality of life were included in this review. Patient satisfaction with treatment and adverse events were also reported on [11].

Search methods

The search strategy recommended by the Editorial Board of the Cochrane Back Review Group [11] was utilised, with additional search terms for physiotherapy intervention, spinal pathology and spinal surgery (see Appendix A: Supplementary Data). The following databases were searched from inception to the end of August 2012: The Cochrane Library, Medline, Embase, CINAHL and The Physiotherapy Evidence Database (PEDro).

Studies not written in English were excluded. Reference lists of included studies were screened for relevant studies.

Data collection and analysis

Two reviewers (SG, JM) independently completed each stage of study selection and data extraction, disagreements were resolved with discussion, and a third reviewer (MD) was consulted if required.

The selection criteria were initially applied to the title and abstract of each study. Full text was obtained where a study was considered potentially relevant, or the information in the title and abstract was insufficient to exclude it. The selection criteria were then applied to the full text articles and those meeting the criteria were included in the review. Where data provided in the full text was insufficient to make a final judgement the study authors were contacted for further clarification.

Data was extracted from the studies using a standardised form and included details about the trial design, participant characteristics, specific intervention(s) and control, outcome measurement (including timing of measurement), and results. Risk of bias was assessed using the Cochrane Collaboration's tool for assessing risk of bias [12] with additional criteria as recommended by the Editorial Board of the Cochrane Back Review Group [11]. As all included studies had been assessed for risk of bias in the PEDro database using the PEDro scale [13] this information was used to assist with quality assessment. In the case of missing or inconsistent data, study authors were contacted to request the raw data and/or further clarification.

Where an outcome variable was reported on in more than one study, the quality of evidence for that outcome variable was assessed using the GRADE approach, as recommended by the Cochrane Collaboration [14]. Treatment effect size was calculated where comparable outcome measures were used across multiple trials.

Results

The electronic search initially retrieved 963 studies. Following title and abstract screening 18 full text articles were sourced, four of which were included in the final review (Figure 1).

The four included studies described RCTs conducted in four different countries (Tables 1 and 2). Three of the included studies compared an additional physiotherapy intervention to standard care [15-17], while the fourth study compared two different methods of patient transfer [18]. Two were based in orthopaedic units [15, 16] and two in neurosurgical units [17, 18].

Three of the studies included patients undergoing a variety of surgical techniques; none of these three studies reported the diagnostic criteria or tools used to determine the need for surgery [16-18]. The remaining study was restricted to patients undergoing a microdiscectomy due to a single level disc prolapse, as confirmed on MRI [15].

Risk of bias

Three of the four included studies were assessed as having a low risk of bias [11] (Table 3). All four studies described a method of random allocation, however only one study explicitly stated using a concealed allocation process [16]. Blinding of the participants, treating physiotherapists, and assessors was not reported in any of the studies, reflecting the physical nature of the intervention and the resulting difficulty in concealing treatment type. A co-intervention was reported in one study [16] with the intervention group receiving alternative post-operative pain relief and additional nutritional supplementation, potentially leading to a performance bias. Baseline data between the intervention and control groups was reported as being comparable in all four studies, however in one study there was no supporting data published [15].

Outcome measurement data was collected as intended and the dropout rate was less than 20% in all four studies. Two studies either had inconsistencies in the published data [15] or had unexplained missing data [16]. Results were analysed by intention to treat in two of the studies [16, 17]. Compliance was reported as being greater than 80% in two of the studies [15, 17] and was not reported in the remaining two. Two of the four studies [16, 17] reported that the sample size allowed sufficient statistical power to detect meaningful change.

Effects of interventions

Due to the varying nature of the interventions provided and a lack of data a meta-analysis was not possible.

Comparison of an additional physiotherapy intervention to standard care

Three studies compared an additional physiotherapy intervention to standard care [15-17] (Table 4). Pain levels were assessed in all three studies. One study [16] reported significantly less pain and less low back pain intensity in the patient group that received additional prehabilitation and early rehabilitation, however the outcome measure and data analysis were unclear. There was no significant difference in back specific functional status reported at any time between the intervention and control groups, in all three studies.

General functional status was measured in all three studies. The intervention groups that received early exercise [15], or prehabilitation and early rehabilitation [16] achieved some but not all of the measured post-operative functional milestones significantly faster than the control groups. The patient group that received prehabilitation and early rehabilitation [16] experienced a significantly earlier discharge from hospital while the patients that received early exercise [15] reported a significantly faster return to work. The group that received neural mobilisation exercises [17] had similar outcomes to the control group in regards to return to work and normal activities.

One study [16] measured quality of life, patient satisfaction and adverse events. Prehabilitation and early rehabilitation had no significant effect on quality of life up to six months post discharge, however significantly more patients were satisfied with their treatment and outcome, and there was no difference in the number of adverse events between the intervention and control groups.

The treatment effect was estimated where comparable outcome measures were used across multiple trials. The standard mean difference was calculated for outcomes measuring back specific functional status, with results favouring physiotherapy intervention in the short to medium term (Figure 2). The overall treatment effect on pain levels and general functional status could not be calculated due to insufficient published data and heterogeneous outcome measures used across the trials. It was not possible to calculate the statistical heterogeneity of the studies due to insufficient data.

Using the GRADE approach [14], results from three studies indicate there is very low quality evidence that additional pre and post-operative exercise may reduce pain, reduce the time taken to achieve some post-operative functional milestones, facilitate an earlier discharge from hospital, or reduce post-operative time off work (Table 4). The level of evidence was downgraded due to the limitations in the design and implementation of two of the three trials [15, 16], the heterogeneity of interventions assessed and outcome measures used, small sample sizes and incomplete reporting of data.

Comparison of two types of transfer techniques

One study [18] compared a prone transfer to a side-lying transfer technique (Table 5). The prone transfer group had marginally less pain than the side-lying transfer group day one post operatively. There were no other significant differences between the two groups in regard to pain or general functional status in the first three days post operatively, and no difference in back specific functional status three months following the surgery.

Discussion

Four studies were identified that met the inclusion criteria, each assessing different interventions and representing only a limited scope of peri-operative physiotherapy care. Although the quality of evidence is assessed as very low this review highlights specific interventions that that may influence patient outcome in this setting. It is possible that both pre and post-operative exercise have a positive effect on patient outcome, therefore the type, timing, intensity and duration of exercise needs to be further investigated. These studies also identified specific outcome variables that may be influenced by physiotherapy intervention and can be used to guide outcome measurement in future research.

Several factors precluded this review from reaching a more clinically relevant conclusion, including the design of the interventions assessed and the outcomes measured. One study assessed the effect of early exercise in addition to standard care

[15], however the additional exercise prescribed was a relatively minor change to the standard care routine and occurred only two to three hours prior to standard care commencing. This study detected significant improvement in some measures of functional status in the intervention group, and a greater treatment effect may have been seen had there been more difference between the intervention and control groups. Conversely, the outcomes that were significantly different between the intervention and control groups need to be interpreted with caution – in one study the intervention group also received alternative analgesia [16]; in all cases the intervention group received a higher intensity of treatment and an increased contact time with the physiotherapist than the control group; and in the two studies that measured achievement of functional milestones as an outcome, the treating physiotherapist who was not blinded to patient group allocation also rated achievement of milestones [15, 16].

The Cochrane Back Review Group [11] recommends inclusion of outcomes assessed in the six main domains of symptoms, satisfaction with treatment, back specific functional status, general functional status, quality of life and adverse events. While all four studies assessed post-operative pain levels and some form of both back specific and general functional status, only one study assessed patient satisfaction, quality of life and adverse events. As a result, these studies may not provide a full picture of the effect of the intervention they were assessing. In addition, facilitating a safe discharge from hospital is one of the primary goals of inpatient physiotherapy [6] however only two of the four studies reported length of stay as a measured outcome. The effect that specific physiotherapy interventions may have on length of stay is a significant factor in designing and justifying inpatient physiotherapy programs and ideally should be included as a routine outcome measure in studies of this nature.

Four previous systematic reviews investigating the effect of physiotherapy in similar population groups but not specific to the inpatient setting have been carried out with comparable results. Two recent Cochrane reviews examined rehabilitation interventions (not specific to physiotherapy) across both the inpatient and outpatient settings following first time lumbar disc surgery [19] and lumbar spinal stenosis [20]. Oosterhuis et al [19] identified 14 studies, two of which commenced rehabilitation immediately following surgery. They concluded there is low quality evidence that there is no benefit in providing additional exercise immediately following surgery in addition to standard post-operative care. All studies identified by McGregor et al [20] commenced intervention at least four weeks post-operatively. The remaining two reviews assessed the effectiveness of physiotherapy intervention in the outpatient setting, one following first time lumbar discectomy [21] and the other following lumbar spinal fusion [22]. These reviews found there was no evidence, or only very low quality evidence respectively to support physiotherapy management in these population groups.

Limitations

The heterogeneous nature of the surgical procedures, the physiotherapy interventions, the standard physiotherapy care provided, and the outcomes assessed limited the comparability of the results. It is possible that non-English publications may add to this literature base, however they were excluded from this review for pragmatic reasons.

Implications for practice

The studies included in this review demonstrated considerable variation in both the interventions and the standard care provided, only touching on the broad topics of mobility and exercise with no research identified that assessed patient advice or education. As a result, this review provides only very low-quality evidence across a narrow scope of physiotherapy practice, and limited clinical guidance for physiotherapists working in this field.

Implications for research

Due to the increasing numbers of spinal surgeries being undertaken and the associated rising costs, it is important that a robust evidence-base is developed to enable physiotherapists to design and implement clinically effective and cost-effective management plans. Further research needs to be targeted towards identifying which of the five main themes of physiotherapy intervention leads to improved patient outcomes and which specific interventions within these themes are the most effective. The setting in which specific interventions should take place also needs to be further investigated, including whether there is a need for pre-operative intervention and whether intervention that does not focus specifically on discharge from hospital needs to be undertaken in the relatively expensive inpatient setting. Larger scale trials are also required in order to determine whether sub-groups of patients, based on the surgical procedure undertaken and factors that predict patient outcome such as pain intensity prior to surgery [23], respond differently to different interventions.

As physiotherapy intervention in the inpatient setting is aimed at both the short-term outcome of a facilitating a safe discharge from hospital, and the medium to long term outcome of promoting post-operative functional recovery, consistent outcome assessment must take place at both ends of this spectrum. This is particularly important due to the demonstrated rising costs associated with an inpatient stay, and the significant financial burden associated with time off work and usual activity.

Conclusion

The results from this systematic review provide limited guidance for physiotherapists working with this population group. Only four RCT's were identified, covering a limited aspect of the pre-operative and acute post-operative physiotherapy management of patients undergoing surgery for the management of degenerative lumbar conditions. Further research into the areas of patient mobility, exercise and provision of education is required, utilising outcome measures that allow for comparison of results across trials.

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Chapter 3: Physiotherapy management of patients undergoing lumbar spinal surgery: a survey of Australian physiotherapists

The systematic review described in Chapter 2 identified a limited number of studies investigating the effectiveness of physiotherapy intervention before and immediately after lumbar spinal surgery. Due to this paucity of research, results from this review provide little guidance regarding the effectiveness of physiotherapy intervention for physiotherapists working in the clinical setting. In addition to the limited number of identified studies, several other concerns regarding applicability to current clinical practice were raised:

- There was considerable heterogeneity in both the routine peri-operative care and the physiotherapy interventions being assessed.
- None of the included studies examined the effectiveness of physiotherapy intervention based on the type of surgical procedure undertaken.
- The tools used to assess outcome varied between the included studies, suggesting that all studies were assessing different patient outcomes.

Despite this lack of evidence, physiotherapy is a common component of the peri-operative management of patients undergoing lumbar spinal surgery across the UK (Rushton et al., 2014; Williamson et al., 2007). Little is known however, about the provision or content of routine peri-operative physiotherapy services in Australian hospitals. A nationwide telephone survey was therefore conducted with the aim of establishing the current peri-operative physiotherapy management of adults undergoing surgery for degenerative lumbar diseases in Australia. This study also aimed to determine whether physiotherapy intervention differed based on the surgical procedure performed, or on the post-operative protocols of individual surgeons.

This study is presented in its published format: Gilmore SG, McClelland JA, Davidson M. (2016). Physiotherapy management of patients undergoing lumbar spinal surgery for degenerative conditions: a survey of Australian physiotherapists. *New Zealand Journal of Physiotherapy* 44(2):105-12.

A copy of the telephone survey questionnaire has been included as an appendix (Appendix V).

Physiotherapy management of patients undergoing lumbar spinal surgery: a survey of Australian physiotherapists

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ABSTRACT

Physiotherapists are commonly involved in the management of patients immediately before and after spinal surgery, however there is currently little known about what constitutes physiotherapy intervention in the hospital setting. This research aimed to describe the current physiotherapy practice in Australia for the peri-operative management of adults undergoing lumbar spinal surgery. A telephone survey was conducted using a structured questionnaire format. All Australian hospitals that admit one or more patients per week for lumbar spinal surgery were invited to take part in the survey. Sixty-four interviews were conducted (response rate 79%). All participating hospitals provided a physiotherapy service for patients undergoing lumbar spinal surgery, with the majority commencing the day following surgery. Physiotherapy intervention consistently included mobility and functional task training, exercise prescription and provision of an educational handout. However, there was considerable variability in the type of exercises prescribed, the advice given regarding post-operative movement and activity restrictions, the use of outcome measurement tools, and referral to inpatient and outpatient physiotherapy services. This survey provides physiotherapists and rehabilitation service providers with information regarding current clinical practice, and identifies the key focus areas for future research into the effectiveness of specific physiotherapy interventions.

Gilmore S, McClelland J, Davidson M (2016) **Physiotherapy management of patients undergoing lumbar spinal surgery: a survey of Australian physiotherapists**. *New Zealand Journal of Physiotherapy 44(2): 105-112. doi: 10.15619/NZJP/44.2.08.*

Key words: Physiotherapy, Survey, Spinal fusion, Discectomy, Laminectomy

INTRODUCTION

Physiotherapists are commonly involved in the management of patients in the peri-operative period, immediately before and after spinal surgery (Rushton et al 2014, Williamson et al 2007). Research carried out in the United Kingdom has found that the focus of peri-operative physiotherapy is typically on the provision of information related to the surgery and ensuring patient readiness for safe discharge. However, the timing of intervention, the number of sessions with a physiotherapist, and the specific interventions provided are all highly variable (Rushton et al 2014, Williamson et al 2007).

While there is a growing body of evidence that rehabilitation interventions commenced four to six weeks following surgery improve patient outcomes, there is little research to guide physiotherapists in designing effective rehabilitation programmes in the peri-operative period (Gilmore et al 2015, Oosterhuis et al 2014). The rate of spinal fusion surgery in Australia increased by 175% between 1997 and 2006 (Harris and Dao 2009). A similar increase of 137% was demonstrated in the United States between 1999 and 2008, with an associated 3.3-fold increase in total hospital charges and a 7.9-fold increase in the total national bill for spinal fusion surgery (Rajee et al 2008). As a result, it is becoming increasingly important for physiotherapists to have access to high quality research that assists with the development of clinically effective and cost effective interventions that optimise patient outcome.

There is currently little known about physiotherapy services provided to patients undergoing spinal surgery in Australian hospitals, including the percentage of hospitals that routinely provide pre and post-operative physiotherapy, and the specific interventions provided. To ensure future research is focused on physiotherapy goals and interventions commonly provided in the clinical setting, an understanding of current physiotherapy practice within Australian hospitals is required.

This research aimed to describe the current peri-operative physiotherapy management of adults undergoing lumbar spinal surgery in Australia. The specific research questions addressed are: a) What constitutes current physiotherapy practice in the pre-operative and post-operative inpatient setting, for the management of adults undergoing lumbar spinal surgery in Australia? b) Is there variation in physiotherapy practice between the different types of lumbar surgery? c) How do individual surgeons' protocols and preferences influence current physiotherapy practice? d) How prevalent is the use of standardised outcome measures, and which measures are most commonly used?

METHODS

Design

A telephone survey using a structured questionnaire format was employed (Appendix 1). The survey was designed to gain a broad, descriptive overview of physiotherapy interventions within a 20 to 30 minute interview. Direct, closed ended questions with pre-determined response categories were based on previous surveys investigating the management of lumbar spinal surgery patients in the UK (McGregor et al 2006, Williamson et al 2007). The survey was piloted on three members of the target population prior to use (Gideon 2012) with minor alterations made to the response categories and structure of the questionnaire. The questionnaire consisted of two sections – General Information (hospital and physiotherapist demographics), and Physiotherapy Intervention. The Physiotherapy Intervention section was divided into seven sub-sections – provision of physiotherapy service, timing and frequency of physiotherapy, advice and education, mobility and functional tasks, exercise, physiotherapy following discharge from the acute setting, and outcome measurement. For each sub-section, participants were asked if physiotherapy intervention varied based on surgical procedure (micro-discectomy, discectomy, laminectomy or fusion) or individual surgeon preferences. If variation existed the sub-section was completed for each variation. A single interviewer conducted all interviews. This study was approved by the La Trobe University Human Ethics Research Committee (FHEC13/146).

Participants

All Australian hospitals that admit one or more patients per week for lumbar spinal surgery were invited to take part in the survey. Hospitals with a neurosurgical and/or orthopaedic service were identified using the MyHospitals website (accessed May 2013). An information package was posted to the physiotherapy department of each hospital. Contact with the hospital physiotherapy department was then made by telephone to determine eligibility, and to obtain the contact details of the senior physiotherapist responsible for the management of patients undergoing lumbar spinal surgery. Up to four attempts were made to contact the appropriate physiotherapist at each hospital. All participants gave informed consent prior to taking part in the survey.

Data analysis

Data were entered into an excel spreadsheet and were analysed using descriptive statistics. Data were analysed for each surgical procedure (laminectomy, micro-discectomy, discectomy, fusion). As laminectomy surgery was the only surgical procedure conducted at all of the participating hospitals, the results of physiotherapy interventions before and after laminectomy surgery are reported, with data for other procedures reported only where physiotherapy service/intervention varied on the basis of procedure. Where within hospital variation in physiotherapy intervention based on individual surgeon preferences was present, each variation has been treated as an additional response. The total numbers reported (N) have been adjusted to reflect the presence of within-hospital variation in intervention.

RESULTS

Participants

A total of 81 hospitals that admitted patients for lumbar spinal surgery were identified and 64 telephone interviews were conducted (79% response rate) between August and December 2013. Of the 17 hospitals that did not participate, two declined. Initial telephone contact was made with the appropriate physiotherapist at two hospitals who were unable to be subsequently contacted to complete the survey. The appropriate physiotherapist was unable to be contacted at the remaining 13 hospitals. Of the 17 hospitals that did not participate three (18%) were publicly funded.

The demographics of the participating hospitals and physiotherapists are described in Table 1. All 64 hospitals admitted patients for laminectomy surgery. Ninety five percent (61/64) admitted patients for fusion surgery, 91% (58/64) for discectomy surgery and 89% (57/64) for micro-discectomy surgery. More than one surgeon performed lumbar spinal surgery at 84% (54/64) of the participating hospitals. Either the structure of the physiotherapy service or the content of the physiotherapy intervention varied based on individual surgeon preferences at just over half (54%, 29/54) of those hospitals.

Table 1: Hospital and physiotherapist demographics (n=64)

Hospital Demographics	n (%)
Funding	
Public	31 (48%)
Private	33 (52%)
Weekly admissions for lumbar surgery	
1-10	47 (73%)
>10	17 (27%)
Surgical procedures undertaken	
Micro-discectomy	57 (89%)
Discectomy	58 (91%)
Laminectomy	64 (100%)
Fusion	61 (95%)
Physiotherapist Demographics	
Employment arrangement	
Employed directly by hospital	52 (81%)
External physiotherapy service	12 (19%)
Gender	
Female	41 (64%)
Male	23 (36%)
Mean years of experience	
Physiotherapist	12 (SD 8.80; range 3-40)
Lumbar spinal surgery	8 (SD 5.48; range 1-25)

Notes: SD, standard deviation.

The overall results of this survey demonstrated very little variation in patient management based on the surgical procedure. Minor differences were reported in the provision of service pre-operatively with patients undergoing lumbar fusions, and post-operatively with undergoing micro-discectomy surgery. The physiotherapy interventions provided also did not differ based on surgical procedure, with only minor differences in exercise prescription. Detailed results are described below.

Pre-operative physiotherapy

A pre-operative physiotherapy service was provided at 39% (25/64) of the hospitals either in a pre-admission clinic (46%, 12/25) or following admission to hospital (54%, 14/25) (Figure 1). All patients undergoing all lumbar spinal surgery procedures were seen pre-operatively by a physiotherapist at 11% (7/64) of hospitals, with an additional two hospitals providing a pre-operative physiotherapy service only to patients undergoing lumbar fusion surgery. Where a pre-operative physiotherapy service was not provided or only some patients were seen prior to surgery, the most common reason was a lack of opportunity due to the patient preadmission or admission process.

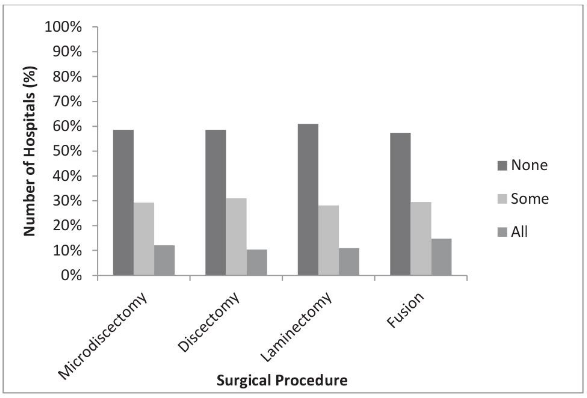

Figure 1: Provision of pre-operative physiotherapy service

The predominant focus of pre-operative physiotherapy was on patient education. Of the hospitals that provided a pre-operative service, 36% (9/25) assessed patient mobility and 12% (3/25) included demonstration of the post-operative exercise programme. No hospitals provided pre-operative exercise or rehabilitation programmes.

Post-operative physiotherapy

All hospitals provided physiotherapy intervention following laminectomy, discectomy and fusion surgery. Two respondents reported patients were not routinely seen following micro-discectomy surgery – in one case patients were seen on a referral only basis, and in the other patients did not receive any physiotherapy intervention due to surgeon preferences.

The timing and frequency of physiotherapy intervention is described in Table 2. At more than 97% of the hospitals, physiotherapy commenced the day following laminectomy, discectomy and fusion surgery, while seven hospitals (12%, 7/57) provided an initial physiotherapy contact on the day of surgery for patients undergoing a micro-discectomy. Patients were most commonly seen once per day (80%, 51/64), while the total number of treatment sessions provided varied between the four surgical procedures. Although physiotherapy generally commenced the day following surgery, 23% (15/66) allowed patients to mobilise the day of surgery following laminectomy, discectomy or fusion surgery, and just under half (41%, 24/59) allowed patients to mobilise on the day of micro-discectomy surgery.

Table 2. Post-operative physiotherapy service

		Microdiscectomy (n=57)		Discectomy (n=58)		Laminectomy (n=64)		Fusion (n=61)	
Initial physiotherapy contact	DOS	7	(12%)	2	(3%)	2	(3%)	1	(2%)
	D1	50	(88%)	56	(97%)	62	(97%)	60	(98%)
Contacts per day	One	47	(82%)	46	(79%)	51	(80%)	48	(79%)
	Two	10	(18%)	12	(21%)	13	(20%)	12	(20%)
	Three+	-		-		-		1	(2%)
Total no. of contacts	One/two	45[a]	(76%)	23[b]	(38%)	17[c]	(26%)	8[d]	(13%)
	Three/four	9[a]	(15%)	25[b]	(42%)	31[c]	(47%)	29[d]	(45%)
	Five/six	3[a]	(5%)	6[b]	(10%)	11[c]	(17%)	13[d]	(20%)
	Seven+	2[a]	(3%)	6[b]	(10%)	7[c]	(11%)	14[d]	(22%)
First allowed to mobilise as per surgical protocol	DOS	24[a]	(41%)	12[b]	(20%)	15[c]	(23%)	13[e]	(19%)
	D1	35[a]	(59%)	47[b]	(78%)	50[c]	(73%)	49[e]	(73%)
	D2	-		1[b]	(2%)	1[c]	(2%)	4[e]	(6%)
	D3+	-		-		-		1[e]	(1%)

Notes: Total numbers include variations in surgical preferences where reported, [a]n=59; [b]n=60; [c]n=66; [d]n=64; [e]n=67; DOS, day of surgery; D1, first post-operative day; D2, second post-operative day; D3, third post-operative day.

Advice and education

The majority of hospitals provided patients with a written handout (85%, 55/65). No respondents reported providing education in any additional format such as video or online resources.

Advice regarding post-operative restrictions varied between hospitals (Figure 2). Variation in post-operative restrictions within hospitals related to individual surgeon preferences rather than the surgical procedure being undertaken. Most respondents (82%, 60/73) reported patients were advised to avoid lifting, with a mean weight restriction of 2.7kg (SD 1.50; range 0.5-5). Fifty-eight percent (43/74) of respondents advised patients to restrict sitting in the post-operative period, with the mean maximum advised sitting time being 25 minutes (SD 15.6; range 0-60).

Figure 2: Post-operative restrictions

Mobility and functional tasks

All participating hospitals provided post-operative education and training in bed and chair transfers and ambulation, and most (86%, 55/64) routinely practised ambulating on stairs prior to discharge. A small number of respondents reported that post-operative physiotherapy included practising picking up objects from the floor (5%, 3/64), transfers on and off the floor (5%, 3/64) and on and off the toilet (3%, 2/64), and ambulating outdoors (2%, 1/64).

Exercise prescription

Post-operative exercises were prescribed at 88% (56/64) of the hospitals. A total of 56 different exercises were described which were subsequently grouped into seven exercise categories: core stability, spinal range of motion (ROM), stretches, strengthening (lower limb and trunk), neural mobilisation, lower limb circulation, and respiratory exercises. A complete list of the exercises described has been provided in Table 3.

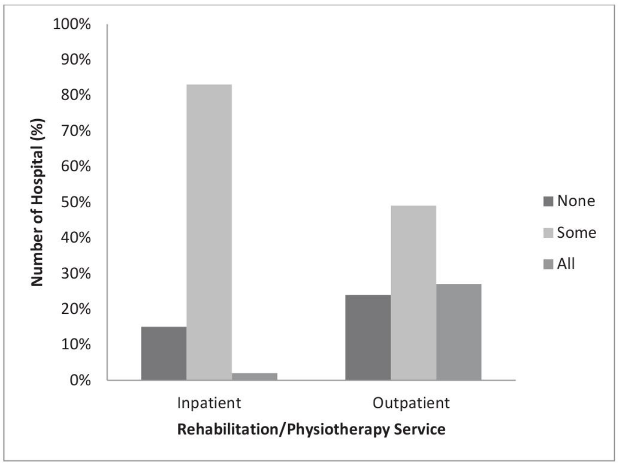

Figure 3: Referral to inpatient and outpatient physiotherapy/rehabilitation services

Table 3: Exercise prescription

	Microdiscectomy n*=50	Discectomy n*=50	Laminectomy n*=56	Fusion n*=53
Core Stabilisation:				
TA activation (CL)	45 (90%)	44 (88%)	50 (89%)	47 (89%)
Pelvic floor activation	8 (16%)	9 (18%)	9 (16%)	8 (15%)
TA activation (st)	4 (8%)	3 (6%)	4 (7%)	4 (8%)
TA activation (sit)	4 (8%)	3 (6%)	4 (7%)	3 (6%)
Hip abduction (CL)	1 (2%)	-	1 (2%)	1 (2%)
TA activation (sit to st)	1 (2%)	-	1 (2%)	1 (2%)
LL circulation:				
Ankle pumps	19 (38%)	22 (44%)	25 (45%)	26 (49%)
Static quadriceps	14 (28%)	18 (36%)	19 (34%)	21 (40%)
Hip/knee flexion	9 (18%)	11 (22%)	11 (20%)	11 (21%)
Static gluteals	5 (10%)	8 (16%)	8 (14%)	9 (17%)
Strengthening:				
Mini squats	10 (20%)	11 (22%)	11 (20%)	10 (19%)
Heel raises (st)	9 (18%)	8 (16%)	10 (18%)	9 (17%)
Hip abduction (st)	7 (14%)	7 (14%)	7 (13%)	8 (15%)
Bridging	6 (12%)	5 (10%)	7 (13%)	6 (11%)
Hip flexion (st)	6 (12%)	5 (10%)	6 (11%)	7 (13%)
Hip extension (st)	4 (8%)	4 (8%)	4 (7%)	4 (8%)
Hip abduction (SL)	4 (8%)	4 (8%)	4 (7%)	4 (8%)
Inner range quads	3 (6%)	3 (6%)	4 (7%)	3 (6%)
Marching on spot	3 (6%)	3 (6%)	3 (5%)	3 (6%)
Squats	2 (4%)	2 (4%)	2 (4%)	3 (6%)
Step ups	2 (4%)	2 (4%)	2 (4%)	2 (4%)
Mini lunge	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Hip flexion (sit)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Knee extension (sit)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Hip adduction (sit)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Sit to stand	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Static abdominal contraction	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Hip extension (prone)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Pulsing abdominal contraction	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Static trunk extension	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Side stepping	-	1 (2%)	1 (2%)	1 (2%)
Spinal ROM:				
Lumbar rotation (supine)	16 (32%)	16 (32%)	18 (32%)	14 (26%)
Hip flexion (supine)	10 (20%)	9 (18%)	11 (20%)	11 (21%)
Pelvic tilt (supine)	7 (14%)	8 (16%)	9 (16%)	8 (15%)
Pelvic tilt (st)	2 (4%)	1 (2%)	2 (4%)	1 (2%)
Pelvic tilt with hip flex (supine)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Pelvic tilt against wall	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Pelvic tilt (sit)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Side flexion (sit)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Neural mobilisation:				
Straight leg raise	4 (8%)	4 (8%)	5 (9%)	5 (9%)
Hip flex with knee flex/ext (supine)	3 (6%)	4 (8%)	4 (7%)	4 (8%)
Ankle df with C ext/pf with C flex (sit)	3 (6%)	3 (6%)	3 (5%)	3 (6%)
Hip flex, knee ext, ankle df (st)	2 (4%)	2 (4%)	2 (4%)	2 (4%)
Femoral glide (SL)	1 (2%)	2 (4%)	2 (4%)	2 (4%)
Supine chin to chest	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Hip and knee flex (st)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Heel over step with ankle pf/df (st)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Active assisted hip ROM (supine)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Hip ROM (st)	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Modified slump	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Respiratory exercises:				
Deep breathing exercises	8 (16%)	10 (20%)	11 (20%)	12 (23%)
Tri-flow	2 (4%)	2 (4%)	2 (4%)	3 (6%)
Stretching:				
Calf stretch	1 (2%)	1 (2%)	1 (2%)	2 (4%)
Psoas major stretch	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Prone lie	1 (2%)	1 (2%)	1 (2%)	1 (2%)
Heel to opposite knee (supine)	1 (2%)	-	1 (2%)	1 (2%)

Notes: * n, number of hospitals where physiotherapy intervention routinely included a post-operative exercise programme; TA, Transverse abdominus; CL, crook lie; st, standing; SL, side lie; LL, Lower limb; flex, flexion; ext, extension; df, dorsiflexion; pf, plantarflexion; ROM, range of motion.

Of the 56 physiotherapy services that routinely prescribed a post-operative exercise programme 88% (49/56) included exercise to target core stabilisation, 45% (25/56) included lower limb circulation exercise, 45% (25/56) included strengthening exercise and 39% (22/56) included exercise to improve spinal ROM. Fourteen respondents (25%) reported including neural mobilisation, 18% (10/56) included respiratory exercises and 5% (3/56) included stretching. There was little variation in the type of exercise prescribed based on the surgical procedure.

Outcome measurement

Patients were assessed using an outcome measurement tool at 83% (53/64) of the hospitals. Of the respondents that reported using at least one outcome measure, 96% (51/53) reported assessing pain using a visual analogue or numeric pain rating scale, while only one hospital (2%) reported using a scale designed to assess disability (Table 4).

Table 4: Outcome measurement

Outcome measurement tool	Reported use
VAS/NPRS	96% (51/53)
Straight leg raise	38% (20/53)
Spinal range of motion	9% (5/53)
10m walk test	6% (3/53)
Oswestry Disability Index	2% (1/53)

Notes: VAS, Visual analogue scale; NPRS, Numeric pain rating scale.

Referral to inpatient and outpatient physiotherapy/ rehabilitation services

Most respondents (83%, 55/66) referred patients to an inpatient rehabilitation unit some of the time (Figure 3), with patient need (ie ongoing rehabilitation goals) being the main factor influencing this decision.

Half of the respondents (49%, 33/67) referred patients to outpatient physiotherapy/rehabilitation some of the time (Figure 3). Patient need was again the main factor influencing this decision. Of the respondents that referred patients to outpatient physiotherapy 27% (14/51) advised to commence physiotherapy within the first two weeks post-operatively, 54% (28/51) advised patients to commence physiotherapy between two and six weeks, and 19% (10/51) advised to commence physiotherapy seven or more weeks following surgery.

DISCUSSION

This survey describes the current physiotherapy management of adults undergoing lumbar spinal surgery in Australian Hospitals. As a total population survey with a high response rate (79%), the results of this survey are likely to be a fairly accurate reflection of physiotherapy management of this patient population.

Physiotherapy service

All hospitals provided a post-operative physiotherapy service, with minimal difference between the hospitals in the timing and frequency of the service provided. This finding is comparable to the results of previous surveys investigating physiotherapy practice following spinal surgery in the United Kingdom (Rushton et al 2014, Williamson et al 2007).

Less than half of the hospitals surveyed provided a pre-operative physiotherapy service, and none of those provided a formal pre-operative rehabilitation programme. The scope of the questionnaire used in this survey does not allow for further interpretation of this observation, however there is some evidence to suggest that pre-operative rehabilitation may improve post-operative outcome (Nielsen et al 2010). Further investigation of the effect of pre-operative rehabilitation, and how to provide this service within the Australian healthcare system is warranted.

Physiotherapy intervention

The overall emphasis of physiotherapy intervention was consistent across the hospitals with a focus on patient education and post-operative mobility. All hospitals provided mobility and functional task training as part of the routine post-operative rehabilitation programme. Physiotherapy intervention included exercise prescription and the provision of educational handouts at most hospitals, however there was variability in the individual exercises prescribed and the advice given regarding movement and activity restrictions. These findings are again comparable to United Kingdom physiotherapy practice following lumbar discectomy (Williamson et al 2007) and lumbar fusion (Rushton et al 2014).

Despite the common focus on patient mobility, initial mobilisation was often delayed from the day of surgery, until the initial physiotherapy contact the day following surgery. While no research has investigated the relationship between mobilisation and patient recovery following spinal surgery, there is evidence to suggest that mobilising on the day of surgery improves both patient outcomes and length of stay in other inpatient surgical populations (Issac et al 2005, Kaneda et al 2007, Larsen et al 2008). It is therefore possible that starting a rehabilitation programme on the day of surgery, with a focus on patient mobility, may reduce the time to achieve functional milestones and reduce overall length of stay.

Core stabilisation exercise was the most common category of exercise prescribed, with transverse abdominus activation the most frequently prescribed exercise. Two recent systematic reviews concluded that core stabilisation exercises may reduce pain and disability in patients with sub-acute, chronic or recurrent low back pain (Brumitt et al 2013, Bystrom et al 2013), however, it is not known whether similar outcomes may be expected in the post spinal surgery population. With the exception of core stabilisation exercise, there was little agreement between the hospitals in the types of exercise prescribed. This lack of consistency likely reflects the limited evidence available to guide physiotherapists in both designing exercise programmes and timing the commencement of the exercise programme. It is also likely that exercise prescription was influenced by post-operative movement restrictions, which varied considerably between the hospitals.

Almost half the hospitals that routinely prescribed a post-operative exercise programme included lower limb circulation exercises, and 18% included respiratory exercises. Evidence suggests that patient mobilisation is adequate to prevent deep vein thrombosis following spinal surgery (Takahashi et al 2012), supported by similar findings in other post surgical populations (Chandrasekaran et al 2009, Pearse et al 2007). In addition, patient mobilisation has been shown to prevent post-operative pulmonary complications without the need for additional exercises (Denehy et al 2003, Silva 2013). As this survey demonstrates, the majority of patients mobilise either the day of or the day following surgery, therefore including these exercises in routine post-operative management may be unnecessary and warrants further evaluation.

Referral to outpatient physiotherapy following discharge was variable. While three quarters of hospitals reported referring patients to an outpatient physiotherapy service, only a third of these routinely referred all patients. Evidence suggests that rehabilitation commencing in the sub-acute phase following lumbar disc surgery improves patient outcome (Oosterhuis et al 2014) therefore further evaluation of referral to outpatient physiotherapy, including patient selection and access to outpatient physiotherapy services, is required. In addition, where no referral to outpatient physiotherapy occurs, intervention provided by the inpatient physiotherapist may have a positive influence on return to work and normal activity. This highlights the need for further research investigating the impact of physiotherapy interventions provided in the inpatient setting on long term patient outcome.

Variation between surgical procedures

Within each hospital, there was little difference in physiotherapy interventions provided across the different surgical procedures. This result likely reflects the focus of intervention being on mobility tasks, which are to be similar irrespective of the surgical procedure. It does, however, raise the question of whether interventions that are targeted to the specific surgical procedure may be more effective at optimising patient outcome within these groups.

Influence of individual surgeon preferences on physiotherapy practice

Just over half of the hospitals with more than one spinal surgeon reported variation in physiotherapy intervention based on differences in surgeon preferences, with the main difference being in the post-operative advice provided to patients regarding movement and activity restriction. These results are consistent with previous surveys conducted with both physiotherapists (Williamson et al 2007) and spinal surgeons (McGregor et al 2006, Rushton et al 2015) in the United Kingdom.

Post-operative movement and activity restrictions are likely to influence the type of exercises prescribed in the post-operative period, education regarding mobility and functional tasks, and the advice given regarding return to work and usual activity. Patients were most commonly advised to restrict movement and activity for four to six weeks post-operatively, potentially delaying active rehabilitation and return to work during this period and leading to additional financial and social burden. Results from one study indicated there was no detrimental effect on patient outcome by having no post-operative restrictions following lumbar discectomy (Carragee et al 1999). While a proportion of the variation in post-operative advice is likely due to the criteria individual surgeons use to determine candidacy for surgery, further research is required to evaluate the necessity of post-operative restrictions and the impact they have on patient outcome in the short and long term.

Outcome measurement

Almost all hospitals reported assessing pain with only a very small number assessing physical function, however the correlation between pain and physical function following spinal surgery has been shown to be limited (DeVine et al 2011). In addition, only one hospital reported using an outcome measurement tool to assess disability despite an increasing focus on assessing disability and recovery of function in the clinical setting.

Current international guidelines for the management of low back pain recommend referral to a specialist anywhere between four weeks and two years after the onset of back pain, and only following a trial of conservative management (Koes et al 2010). It is therefore likely that the majority of patients undergoing lumbar spinal surgery have been living with considerable functional limitation for some time. The use of appropriate outcome measures assessing physical function pre and post-operatively would provide valuable information to guide return to work and other activities of daily living during the rehabilitation period.

Clinical relevance

The information collected from this survey provides a description of current physiotherapy practice in Australian hospitals. While there is consensus that this patient population benefits from physiotherapy intervention in this setting, there is considerable variation in the physiotherapy interventions provided, an observation consistent with United Kingdom physiotherapy practice following lumbar discectomy (Williamson et al 2007) and lumbar fusion (Rushton et al 2014). This finding likely reflects the limited research available to guide clinicians working in the acute hospital setting. This information should therefore be used to inform clinicians about current practice, but not be regarded as "gold standard". Further research is required to develop clear rehabilitation guidelines to facilitate optimal outcome for patients undergoing lumbar spinal surgery.

Study limitations

Using a structured questionnaire format with predominantly closed questions and pre-determined response categories allowed for the collection of data across a range of categories within a short timeframe. However, it also limited participant responses with minimal opportunity to elaborate on answers provided. Several areas of current practice requiring further analysis have been identified, including referral processes to outpatient physiotherapy services and the use of outcome measures in standard practice. Additional information regarding the influence of pre-operative diagnosis and symptoms, patient age, and co-morbidities on the choice of interventions provided may also have allowed for a more in depth analysis of data.

Publicly and privately funded hospitals were equally represented in the responding hospitals, while most (82%) of the non-responding hospitals were privately funded. It is possible that data from the non-responding hospitals may have influenced the results of this survey, however due to the variability in responses received it is likely that the overall conclusions of this study would remain unchanged.

CONCLUSION

This survey demonstrates considerable variability in physiotherapy management of patients following lumbar spinal surgery, which likely reflects the paucity of research investigating the relationship between peri-operative physiotherapy intervention and patient outcome. This survey provides physiotherapists and health service managers with information regarding current clinical practice, and identifies the key focus areas for future research into the effectiveness of physiotherapy interventions for people undergoing spinal surgery.

KEY POINTS

1. Almost all patients undergoing lumbar spinal surgery in Australia are seen by a physiotherapist during their hospital admission, with the overall goals of physiotherapy intervention focusing on patient education, post-operative mobility and exercise prescription.
2. Physiotherapy intervention does not vary based on the type of surgical procedure undertaken.
3. Surgeon specific protocols guide post-operative restrictions, and therefore influence the structure and timing of the physiotherapy rehabilitation programme.
4. There is limited use of outcome measurement tools to assess physical function in the acute setting following lumbar spinal surgery.

DISCLOSURES

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Chapter 4: Measuring walking after lumbar surgery

The survey of current physiotherapy practice described in Chapter 3 identified two main findings that may be used to guide further research: a) almost all patients undergoing lumbar spine surgery in Australia are seen by a physiotherapist before and/or after surgery, and b) physiotherapists provided education and/or training on mobility tasks and walking. This information is consistent with current practice in the UK (Rushton et al., 2014; Williamson et al., 2007), and indicates that considerable resources are being spent on a patient group where there is very little evidence to guide clinical practice.

Although increasing walking after lumbar surgery is a common goal of treatment, it is unknown whether increased physical activity improves post-operative outcomes. The link between low levels of physical activity and poor general health has been well established (Warburton et al., 2010), with the World Health Organisation listing insufficient physcial activity as the fourth highest risk factor for global mortality (World Health Organisation, 2010). The current Australian Physical Activity and Sedentary Behaviour Guidelines recommend that adults perform at least two and a half hours of moderate intensity physical activity each week, such as brisk walking (Australian Government Department of Health, 2012), which is consistent with international physical activity guidelines (Tremblay et al., 2011; World Health Organisation, 2010). However, it is estimated that less than half of all Australian adults meet these recommendations (Australian Bureau of Statistics, 2013), with similar trends seen worldwide (Guthold et al., 2018).

While there are no guidelines specific to physical activity in patients after lumbar surgery, maintaining a physically active lifestyle is consistently recommended as part of evidence-based guidelines for the management of low back pain (Koes et al, 2010). There is also a growing evidence base to suggest that increasing post-operative activity improves functional outcome and reduces the rate of complications in other post-surgical populations (Kalisch et al., 2013). It is therefore likely that increasing physical activity immediately after lumbar surgery will have a similar positive effect on recovery, including improving patient outcomes and reducing the risk of post-operative complications. However, while this hypothesis has a strong theoretical basis, to date there has been no research to investigate whether increased physical activity levels early after lumbar surgery is associated with improved patient outcome.

There has been a growth in the number of observational studies aiming to identify patient variables that are predictive of either very good or poor outcome after lumbar surgery, as shown in the recent systematic review by Rushton et al. (2018). Several studies have investigated the impact of pre-operative mobility status and/or disability on post-operative outcome (Chotai et al., 2017; Hey et al., 2017; Kanaan et al., 2015; Leonard et al., 2017; Mancuso et al., 2017; Paulson et al., 2017; Pearson et al., 2012). However, only one known study has explored the relationship between post-operative physical activity and improved recovery of longer-term function. Kanaan et al. (2014) investigated whether distance walked during an inpatient hospital admission following surgery for lumbar spinal stenosis was associated with discharge destination. This study found that increased walking distance early after surgery was predictive of discharge home rather than a rehabilitation facility. However, walking distance was based on the distance walked during physiotherapy sessions as documented by the physiotherapist in the patient notes. As this did not take into account walking outside of physiotherapy sessions, this may not be an accurate reflection of true walking distance. Further research is therefore required to confirm this relationship between walking and patient outcome, using a valid and accurate measure to quantify walking.

4.1. The validity of using activity monitors to detect step count after lumbar fusion surgery

Traditionally, physical activity has been measured using patient reported questionnaires. However, these questionnaires have only moderate validity when measuring frequency, duration and intensity of physical activity (Helmerhorst et al., 2012). As an alternative to questionnaires, devices designed to directly measure step count and other physical activity parameters have been developed using accelerometry. Over the last decade there has been considerable advancement in accelerometer technology, both those developed specifically for research purposes and personal activity monitors available for use in the general population. Alongside this advancement in technology there has been rapid growth in the use of activity monitors, again in both the research setting and in the general population. This growth presents a number of opportunities for researchers and clinicians interested in measuring and promoting physical activity, particularly as commercially available monitors may be a potentially cost effective and easily accessible alternative to monitors developed for research purposes. However, while a number of accelerometers with a step count function are available, there is limited evidence regarding the validity of accelerometers when recording step count in patients with slow or irregular gait patterns, as is typical in the post lumbar surgery population.

To address this knowledge gap, we designed a study to evaluate the validity of three activity monitors, one designed for in-depth analysis of physical activity (ActivPAL3©; PAL Technologies, Glasgow, UK), and two commercially available devices (the Fitbit Flex©; Fitbit Inc., San Francisco, USA and the Jawbone Up Move©; Jawbone, San Francisco, USA). The ActivPAL3© accelerometer was chosen as it was worn fixed to the thigh rather than a waistband or wrist strap, and was therefore unlikely to be affected by an irregular arm swing or the use of a gait aid. The commercially available monitors were included to evaluate the potential of using easily accessible, low cost monitors as an alternative to the ActivPAL3©. As it was hypothesised that the accuracy of the wrist worn monitors may be reduced when a gait aid was used, the wrist worn monitors were tested on the wrist, and on the thigh in the same position as the ActivPAL3©. Both the Fitbit Flex© and the Jawbone Up Move© had sensor devices that could be removed from the wrist strap to be fixed to the thigh.

The research questions addressed were:

1. Do the ActivPAL3©, Fitbit Flex© and Jawbone Up Move© activity monitors provide a valid measure of step count within the first three days after lumbar spinal fusion?
2. Does the use of a gait aid affect the validity of the wrist worn activity monitors (Fitbit Flex© and Jawbone Up Move©)?
3. Do the wrist worn activity monitors (Fitbit Flex© and Jawbone Up Move©) provide a valid measure of step count when worn on the thigh?
4. Is there a correlation between the accuracy of each activity monitor and average walking speed over a two-minute test period?

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Gilmore SJ, Davidson M, Hahne AJ, McClelland JA. (2018). The validity of using activity monitors to detect step count after lumbar fusion surgery. *Disability and Rehabilitation* 16:1-6

The Figures and Tables referred to in the published text are included as an appendix (Appendix VI).

The Validity of using Activity Monitors to Detect Step Count after Lumbar Fusion Surgery.

Abstract

Purpose

Measuring step count using activity monitors is an increasingly popular method of quantifying physical activity, however it is unknown whether gait irregularities or the use of gait aids affect the accuracy of these devices. This study evaluates the validity of the ActivPAL3, Fitbit Flex and Jawbone UP Move activity monitors for measuring step count in hospital inpatients after lumbar fusion.

Methods

The ActivPAL3 was tested on the thigh, the Fitbit and the Jawbone were tested on the wrist and thigh, each monitor was tested 20 times. Validity was examined by calculating the percentage of steps detected by each monitor compared to the criterion measure of observed step count, the Standard Error of Measurement, and the Intraclass Correlation Coefficient.

Results

The ActivPAL3 detected 85% (SD 27%) of observed steps. On the wrist, the Fitbit detected 24% (SD 34%) and the Jawbone detected 17% (SD 40%) of observed steps. On the thigh, the Fitbit detected 66% (SD 42%) and the Jawbone detected 22% (SD 35%) of observed steps.

Conclusion

The ActivPAL3 activity monitor is a sufficiently valid tool to detect step count immediately after lumbar fusion. Wrist worn monitors are not recommended in this population, particularly with patients using gait aids.

Introduction

Increasing activity levels in the hospital inpatient setting is a key component of post-operative care. Evidence indicates that increased activity leads to reduced length of hospital stay, a reduction in post-operative complications, and improved functional outcomes [1]. While the benefits of increasing physical activity in hospital inpatients are well established, further research is required to determine the optimal amount of activity needed to achieve these benefits, and to do this we need to be able to accurately measure physical activity in hospital inpatient populations. The lumbar fusion population is one example of a patient group in which increasing physical activity is an important post-operative goal, and quantifying activity levels may ultimately lead to a better understanding of recovery and improved outcomes.

Historically, physical activity has been measured using direct observation or self-reported questionnaires. While direct observation may be recommended to evaluate activity, it is time consuming and impractical over longer time periods, and the majority of questionnaires reporting frequency and duration of activity have been shown to have moderate validity at best [2]. More recently, using accelerometry to record step count and estimate energy expenditure has become the measurement method of choice. A number of accelerometers have been developed for use in the research setting, and a growing range of personal activity monitors are commercially available. The devices designed for personal use potentially provide a cost effective and readily available alternative to activity monitors typically used in research, although the accuracy of these monitors in patient populations must first be established.

A number of studies have investigated the validity of activity monitors to measure step count, both those typically used in research and commercially available devices. The ActivPAL accelerometer (PAL Technologies, Glasgow, UK), provides a valid measure of step count in healthy adults [4-6], and there is evidence it accurately measures step count in patient populations [7,8]. Studies investigating the validity of commercially available devices, such as the Fitbit (Fitbit Inc., San Francisco, USA) and Jawbone (Jawbone, San

Francisco, USA), have produced variable results [9-13], and their validity in the hospital inpatient setting needs to be further investigated.

Resuming walking after lumbar fusion is a key component of post-operative rehabilitation [14,15]. Several studies have used activity monitors to quantify walking using step count [16,17], however whether activity monitors provide a valid measure of step count in this population is yet unknown. It is probable that patients will have a slow, irregular gait pattern [18,19] after surgery, which potentially impacts the accuracy of an activity monitor [6-8]. It is also likely that these patients will require a gait aid in the immediate post-operative period. As gait aids reduce or eliminate arm swing, they potentially impact the accuracy of wrist worn monitors [13].

This study aimed to evaluate the validity of the ActivPAL3, Fitbit Flex and Jawbone Up Move activity monitors, when measuring step count in patients within the first three days after lumbar fusion surgery in comparison to the criterion measure of observed step count. The data from the wrist worn monitors (Fitbit Flex and Jawbone Up Move) were examined to assess whether using a gait aid affects the validity of the monitor. The wrist worn monitors were also trialled on the thigh, as a potential alternative position if wrist accuracy is reduced in participants that use a gait aid. Finally, to assess whether monitor accuracy was impacted by gait speed, the correlation between the accuracy of each activity monitor and average walking speed over the two-minute test period was calculated.

Methods

This study evaluated the concurrent validity of the ActivPAL3, Fitbit Flex and Jawbone UP Move activity monitors when compared to observed step count, in patients immediately after lumbar fusion surgery. Ethics approval was obtained from the St Vincent's Hospital Melbourne Human Research Ethics Committee (Reference: LRR 098/15).

Participants were recruited from St Vincent's Private Hospital Melbourne between February and August 2016, as a sub-group of a concomitant trial [20].

Patients aged 18 years and older undergoing lumbar spinal fusion surgery were invited to participate. Patients were excluded if they were undergoing surgery for the management of lumbar fractures or tumours, were unable to provide informed consent, had comorbidities that resulted in impaired physical function, or were unable to stand or walk for a minimum of two minutes on the day of testing.

Potential participants were identified from neurosurgical theatre lists. Eligible patients were provided with a participant information statement and consent form prior to surgery, and were contacted during the week before surgery to explain the research and confirm eligibility. Written informed consent was obtained from all participants. One researcher, a physiotherapist with eight years of experience working on a spinal surgery unit, collected all data.

Three activity monitors were tested: the ActivPAL3 accelerometer, a monitor typically used in research that is worn fixed to the anterior thigh [21]. The Fitbit Flex and the Jawbone UP Move are both commercially available monitors designed to monitor personal physical activity. The ActivPAL3 was chosen as it could be fixed to the thigh and required minimal input from the user, it did not have features that could potentially irritate a lumbar wound such as a waistband, and due to placement on the thigh rather than wrist it was unlikely to be affected by the use of gait aids. The commercially available monitors were included to evaluate the potential of using easily accessible, low cost monitors as an alternative to the ActivPAL3. For this reason, both the Fitbit and Jawbone were tested in two positions: (i) worn on the wrist in the wrist strap supplied with the monitor, and (ii) taped to the thigh replicating the position of the ActivPAL3. Both were tested as they were purchased, using their “off the shelf” specifications.

Testing took place on the second or third post-operative day. Each participant tested either two or three activity monitors: all 40 participants wore one Fitbit and one Jawbone on the wrist or thigh (20 trials per monitor per position), and 20 participants wore an ActivPAL3 [22]. All monitors were worn on the dominant side.

Participant characteristics including date of birth, height and weight were entered into the user profiles of the Fitbit and Jawbone smartphone applications, and the Fitbit and Jawbone were synced with their applications. Participants were instructed to walk around the hospital ward at a comfortable pace for two minutes, using their prescribed walking aid if required. The two-minute time period was chosen to maximise the time that step count measured without excluding participants with a limited walking capacity. The researcher measured the distance walked with a measuring wheel as the test was being completed. The timed walk was video recorded, and the number of steps taken over the two minutes was counted, representing the observed step count (criterion measure). One "step" was defined as lifting one foot and returning it to the floor. All videos recordings were reviewed by a single researcher. The number of steps on the video recording was repeated twice, if the step count over the two repetitions differed it was repeated until consensus was reached. ActivPAL3 data were downloaded using software provided by PAL Technologies. The number of steps detected by the ActivPAL3 device during the timed walk test was obtained from the downloaded data. On completing the timed walk the Fitbit and Jawbone were re-synced with the smartphone application, the step count over the two-minute time period was recorded from the smartphone application.

Data were analysed using SPSS version 24 (IBM, New York, USA). Participant characteristics were analysed using descriptive statistics. All statistical analyses of the activity monitor data compared the steps detected by the monitors to the step count observed on the video recording of the timed walk test (observed step count). Direct observation is the accepted criterion measure for assessing step count, and has been previously used as the criterion measure in similar studies [12, 13, 23].

To evaluate the validity of the ActivPAL3, Fitbit and Jawbone when compared to the observed step count, the following analyses were conducted: I. The percentage of steps detected by each activity monitor was determined by calculating the number of steps detected by the activity monitor, as a proportion of the observed step count; II. The standard error of measurement (SEM) was calculated using the standard deviation of the difference between the number of steps detected by each activity monitor and the observed step count [24]; and III. The Intraclass Correlation Coefficient (ICC, model 2,1) was used to determine the association between the number of steps detected by each activity monitor, and the observed step count. Bland Altman plots were created to illustrate the limits of agreement for each monitor [22].

An independent t-test was used to evaluate whether using a gait aid affected the accuracy of the wrist worn activity monitors. The percentage of observed steps detected in the trials without a gait aid was compared to the percentage of observed steps detected while using a gait aid. An independent t-test was then used to compare the percentage of observed steps detected by the Fitbit and Jawbone when trialled on the wrist compared to the thigh. To assess whether walking speed impacted monitor accuracy, the correlation between the percentage of steps detected by each monitor and the average walking speed over the two-minute timed walk was calculated using the Pearson Correlation Coefficient.

Results

There were 40 participants (65% female), with a mean age of 65 years (SD 13.31). The majority of participants had a single level fusion (80%). Twenty-two participants used a gait aid during testing: 10 while testing the Fitbit on the wrist and 12 while testing the Jawbone on the wrist. All gait aids used were wheeled walking frames (Table 1).

A total of 100 activity monitor trials were completed: the ActivPAL3 was trialled 20 times, the Fitbit and Jawbone were each trialled 20 times on the wrist and 20 times on the thigh. One ActivPAL3 was not returned to the researchers on completion of the study and two ActivPAL3 monitors failed to any record data. On two occasions the personal activity monitors did not sync with the smartphone application either during or after testing, once with the Fitbit and once with the Jawbone, both in the thigh position. Data analysis was therefore conducted on a total of 95 trials: 17 trials with the ActivPAL3, 20 trials with the Fitbit and Jawbone on the wrist, and 19 trials with the Fitbit and Jawbone on the thigh.

The overall percentage of steps detected by the three activity monitors is described in Table 2, the individual test results are included in the Supplementary Tables (S1 and S2). The ActivPAL3 detected a mean of 85% (SD 27%) of the observed steps, with a SEM of 23.2 steps and an ICC of 0.81 (95% CI 0.37 - 0.94). Bland Altman analysis demonstrated a trend towards underestimating step count (Figure 1). The percentage of steps detected by the ActivPAL3 ranged from 15% to 100%, 85% or more of the observed steps were detected in 14 of the 17 trials. The Fitbit on the wrist detected a mean of 24% (SD 34%) steps, with a SEM of 36.2 and an ICC of 0.35 (95% CI -0.17 - 0.74). The Fitbit did not detect any steps during 10 of the 20 trials on the wrist. The Jawbone on the wrist detected a mean of 17% (SD 40%) of the steps with a SEM of 40.5 and an ICC of 0.36 (95% CI -0.17 - 0.74). The Jawbone did not detect any steps in 16 of the 20 trials on the wrist.

In the group of participants that used a gait aid, the Fitbit on the wrist detected a mean of 3% (SD 18%) of the observed steps, compared to 42% (SD 35%) in the group that did not use an aid (Table 2), however this difference was not statistically significant. The wrist worn Fitbit did not detect any steps during seven of the ten of the tests performed with a gait aid. When worn on the thigh, the Fitbit detected a mean of 66% (SD 42%) of the observed steps, with a SEM of 35.8 (Table 2) and ICC of 0.71 (95% CI -0.02 - 0.91). The mean percentage of steps detected by the Fitbit was significantly higher when worn on the thigh compared to the wrist ($p \leq 0.01$).

In the group with no gait aid, the Jawbone detected a mean of 43% (SD 52%) of observed steps, with SEM of 58.1 and an ICC of 0.46 95% (CI -0.36 - 0.87). The wrist worn Jawbone did not detect any steps during any of the 12 trials where participants used a gait aid, the ICC, SEM and Bland Altman Plots were therefore not calculated for this group. The mean percentage of steps detected by the Jawbone on the thigh was similar to that on the wrist (Table 2), with an ICC of 0.11 (95% CI -0.15 - 0.44). Thirteen of the 19

Jawbone trials on the thigh did not detect any steps. There was no significant difference in the accuracy of the Jawbone between the wrist and thigh position.

Bland Altman analysis reflected the data analysis described above. The Fitbit and Jawbone demonstrated wide levels of agreement and a trend to underestimate step count on both the wrist (Figure 2) and thigh (Figure 3).

The mean distance walked over the two-minute walk was 64m, representing an average walking speed of 0.53m/s. There was no significant correlation between the percentage of steps detected and average walking speed for the ActivPAL3 monitor (Table 3). The correlation between the percentage of steps detected and the average walking speed was significant for both the Fitbit ($p>0.01$) and Jawbone ($p>0.05$) on the wrist with no gait aid, and for the Fitbit on the thigh ($p>0.05$). These results indicate the accuracy of the Fitbit and Jawbone reduces as walking speed slows.

Discussion

The ActivPAL3 had a strong correlation with the observed step count and the highest mean step detection rate at 85%, however the margin of error may be high as indicated by the relatively high standard error of measurement. When worn on the wrist, the Fitbit and Jawbone both had a low overall mean step detection rate, which was extremely low in patients that used a gait aid during testing. On the thigh, the Jawbone also had a low mean step detection rate. The percentage of steps detected by the Fitbit was significantly higher on the thigh than the wrist, however this figure was still only moderate at 66%.

While the ActivPAL3 demonstrated the highest mean percentage of steps detected of the three monitors, one ActivPAL3 trial recorded an accuracy of only 15%. This may have been due to individual monitor error, monitor placement error, or thigh movement during the gait cycle not being within the ActivPAL3 algorithm designed to detect a step, for example slow speed of movement. While the average walking speed over the two minute test period was slower than normal [25], there was no significant correlation between average walking speed over the two minutes and the accuracy of the ActivPAL3. Further examination of the impact of average walking speed on monitor accuracy is required to determine whether a minimum speed is necessary to achieve adequate monitor accuracy.

While the had authors hypothesised that the wrist worn monitors would have a lower step detection rate when used with a gait aid, the overall accuracy of the Fitbit and the Jawbone was surprisingly low. Previous studies investigating the validity of the Fitbit and Jawbone have produced variable results [9-13]. Results from this study are consistent with recent research investigating validity of the Fitbit Flex and Jawbone UP in older adults, in which both monitors demonstrated low to moderate correlation with observed step count, particularly when participants had an impaired gait pattern or used a gait aid [13].

The low step detection rate of the wrist worn monitors while using a gait aid is likely explained by the activity monitors not detecting movement due to the absence of arm swing during the gait cycle, which may also explain the lower accuracy of the Fitbit and Jawbone while worn on the wrist in the group of participants that did not use a gait aid. Arm swing has been shown to reduce in slower paced walking in both healthy individuals [26] and those with chronic low back pain due to lumbar disc herniation [18]. Huang et al. [18] also found people with chronic back pain have an abnormal arm-swing relative to thoracic movement and the stepping cycle. As low amplitude arm swing which may be out of phase with the stepping cycle is also probable in the lumbar fusion population, this may impact the accuracy of wrist worn activity monitors that rely on arm swing to detect steps. This theory is supported by the correlation between accuracy of the Fitbit and Jawbone and average walking speed, demonstrating that monitor accuracy declines as walking speed slows. In addition, the high proportion of Fitbit and Jawbone tests in which no steps were detected suggests that the monitors may require a minimum walking speed to activate the accelerometer, further limiting their use in patient populations with a very slow average walking speed.

The Fitbit detected significantly more steps when worn on the thigh than on the wrist, showing a strong correlation with the observed step count. As the Fitbit fixed to the thigh relies on thigh movement rather than arm swing, gait irregularities such as an irregular arm swing will not impact on monitor accuracy. Further research is needed to explore the potential for the step detection rate of the Fitbit to improve with modification to the accelerometer algorithm, designed specifically for the thigh position. As the intention of this study was to investigate the validity of the commercially available monitors as they were purchased, exploring how changes to the algorithm may improve the validity of the devices was beyond the scope of this study.

Study limitations

Study limitations include a small sample size with the possibility of selection bias. Neither the observers nor participants were blinded to the measurement devices. As the timed walk test was of a short and specific duration, the results of this study may not accurately reflect the ability of the activity monitors to detect step count in a free-living setting. In addition, the definition used to measure a "step" may have differed between the observed step count and the activity monitor algorithms, potentially reducing the agreement between the two measures.

Conclusion

The ActivPAL3 activity monitor is a sufficiently valid tool to detect step count in patients immediately following lumbar fusion. The Fitbit Flex and Jawbone UP Move are not recommended for use in this population due to a low step detection rate, particularly in patients using gait aids.

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Chapter 5: Does walking after lumbar spinal surgery predict recovery of function at six months? Protocol for a prospective cohort study

The survey of current practice as outlined in Chapter 3 found that the majority of patients undergoing lumbar spinal surgery were seen by a physiotherapist during their inpatient hospital admission. There was considerable variability in the physiotherapy interventions provided which was consistent with the findings of similar surveys carried out in the UK (Rushton et al, 2014; Williamson et al., 2007), and unsurprising given the lack of evidence to guide practice (Gilmore et al., 2015; McGregor et al., 2013; Oosterhuis et al., 2013; Rushton et al., 2011).

Despite the overall variability in practice, there was a consistent focus on delivering interventions with the intention of improving post-operative mobility and resume walking. Based on this finding, combined with the growing body of evidence supporting the importance of increasing walking in the inpatient hospital setting (Kalisch et al., 2013), the following study protocol was designed to further investigate the role that walking plays in recovery after lumbar surgery.

The primary aim of this protocol was to describe the methodology for a prospective study exploring whether the amount of walking patients do in the week following lumbar spinal surgery, is predictive of improvement in physical function at six months (presented in Chapter 7). The secondary aims were to describe patient activity patterns in the first week after surgery, and to identify factors that may influence the amount of activity patients undertake in the first post-operative week (presented in Chapter 6).

This study protocol is presented in its published format: Gilmore SJ, McClelland JA, Davidson M. (2016). Does walking after lumbar spinal surgery predict recovery of function at six months? Protocol for a prospective cohort study. *BMC Musculoskeletal Disorders* 17:472-8.

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STUDY PROTOCOL Open Access

Does walking after lumbar spinal surgery predict recovery of function at six months? Protocol for a prospective cohort study

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Abstract

Background: Physiotherapists are commonly involved in the management of patients immediately following lumbar spinal surgery. There is however, very little research to guide physiotherapy intervention in the acute post-operative period, and the advice provided to patients regarding post-operative walking and physical activity has been shown to be highly variable.

The primary aim of this research is to establish whether the amount of walking patients perform in the week following lumbar spinal surgery predicts improvement in function at 6 months.

Methods: This study will be a prospective cohort study design, with a projected sample size of 250 participants. Patients undergoing surgery for the management of a disc prolapse, degenerative disc disease, lumbar spinal stenosis and/or degenerative spondylolysthesis will be invited to participate in this study.

Outcome measurement will take place pre-operatively and at six months post-operatively. The primary outcome variable will be self-reported function, measured using the Modified Oswestry Disability Questionnaire and the physical component summary of the SF-36.

Each participant will be fitted with an activPAL3 accelerometer to be worn for the first seven post-operative days. This accelerometer will record time spent in active versus sedentary postures, step count and time spent walking. Multivariable logistic regression analysis will be used to investigate the relationship between the total time spent walking over the first seven post-operative days, and outcome at six months.

Discussion: The results from this research will help to guide patient management during the inpatient phase, by identifying patients who are at risk of poorer outcome due to limited walking time. These patients may benefit from ongoing rehabilitation and outpatient physiotherapy services. This information will also provide a foundation for further research into interventions designed to optimise post-operative activity.

Trial registration: ACTRN12616000747426, retrospectively registered 7th June 2016.

Keywords: Physical activity, Physiotherapy, Rehabilitation, Lumbar fusion, Discectomy, Laminectomy

Background

Low back pain is the leading cause of disability worldwide, with both the rate of low back pain and the associated burden of disability expected to increase as the global population ages [1]. Clinical guidelines consistently recommend conservative management of low back pain, however surgical intervention may be indicated where conservative management is not successful [2]. While there is a growing body of evidence to support surgical management of low back conditions [3–5], up to 40 % of patients continue to report no or minimal improvement in post-operative function [6]. This figure highlights the need for evidence based, effective rehabilitation programs designed to optimise post-operative recovery.

Physiotherapy is a common component of the management of patients undergoing lumbar spinal surgery at the majority of hospitals in Australia and the UK [7–9]. The goals of physiotherapy intervention during the inpatient admission consistently focus on achieving independence

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with mobility and functional tasks, and providing advice and education about post-operative walking and physical activity [7–9]. The specific interventions required to achieve these goals however, are poorly understood. There is very little research to guide physiotherapy intervention in the acute post-operative period [10, 11], with considerable variability in the advice provided to patients regarding post-operative walking and general activity [7–9, 12].

There are a growing number of studies aimed at identifying factors that predict outcome following lumbar spinal surgery. These include patient demographics (age [13], smoking status [14–16]), co-morbidities (diabetes [14, 16, 17], obesity [14, 18]), impairments (pain and sensory changes [14]), and psycho-social factors (depression [19, 20], fear avoidance [21]). These factors play an important role in selecting patients appropriate for surgical intervention. There is however, limited scope to modify any of these variables particularly in the acute post-operative phase, to influence patient rehabilitation or functional recovery.

Clinical guidelines for the management of low back pain consistently recommend staying active [2] with evidence suggesting that maintaining an active lifestyle leads to reduced pain and improved functional outcome [22]. It is not known whether this positive association can be translated into the post-surgical population, or more specifically, whether people who participate in more physical activity have better outcomes following surgery. In other post-surgical populations, evidence suggests that early and increased walking improves functional outcome and reduces the rate of post-operative complications [23]. It is therefore likely that increased walking immediately following lumbar spinal surgery leads to similarly improved outcomes.

Accelerometers are becoming an increasing popular method of quantifying physical activity, and have been shown to provide an accurate measure of step count, time spent walking and distance walked. [24–26] Two recent studies have used accelerometry to describe the improvement in physical activity following lumbar spinal surgery. Mobbs et al. [27] reported a significant improvement in step count and distance walked three months after lumbar spinal surgery, and Schulte et al. [28] reported a significant improvement in step count three months after surgery for lumbar stenosis. There are however, no known studies describing walking immediately following spinal surgery, or how the amount of walking in this period impacts longer-term functional recovery.

We know that gait assessment, and advice regarding walking and return to physical activity already forms a key component of physiotherapy intervention immediately following lumbar surgery. Establishing how much walking patients currently do, and how walking in the period immediately following surgery impacts longer term functional outcome will enable physiotherapists to individualise patient management to achieve optimal outcomes. It will also help to identify patients who are unable to achieve the minimum amount of walking associated with improved outcomes, and who may therefore require more intensive rehabilitation programmes.

Method

Aims

This research will investigate the relationship between the time spent walking in the week following lumbar surgery, and recovery of physical function. The primary aim is to establish whether the amount of walking patients do in the week following lumbar spinal surgery predicts improvement in function at six months. The data collected will also be used to generate an activity profile to describe the overall patterns of activity in the first post-operative week, and to identify factors that may influence the amount of activity patients undertake.

The research questions are:

1. Does the amount of time spent walking during the week after lumbar spinal surgery predict improvement in function at six months?
2. What proportion of time do patients spend performing active tasks (standing and walking) compared to sedentary behaviour (sitting and lying) in the week following lumbar spinal surgery?
3. Is the amount of time spent walking in the first post-operative week influenced by restricted pre or post operative physical function, post-operative pain or complications, or the need for supervision while walking?

Design

This study will be a prospective cohort study design. Ethics approval from the St Vincent's Hospital Melbourne Human Research Ethics Committee's has been obtained (Reference: LRR 098/15).

Participants

Participants will be recruited from St Vincent's Private Hospital, Fitzroy (SVPHF) over a six-month period. All patients aged 18 years and older undergoing surgery for the management of a disc prolapse, degenerative disc disease, lumbar spinal stenosis and/or degenerative spondylolysthesis will be invited to participate. There will be no restriction on the nature or duration of pre-operative symptoms. Patients will be excluded if they are undergoing surgery for the management of lumbar fractures or tumours, have a history of dementia or cognitive impairment or an inability to provide informed consent, or have a history of a neurological or musculoskeletal condition resulting in progressive impairment of physical function (for example, multiple sclerosis or rheumatoid arthritis). In cases where surgery includes both lumbar and thoracic vertebrae, patients will be eligible if 50 % or more of the vertebra involved are in the lumbar region.

Study procedure

Recruitment and sample size

The recommended sample size for logistic regression analysis is a minimum of 5 outcome events per predictor variable (EPV) [29]. The maximum number of variables to be analysed in this study is 15 giving a minimum sample size of 150. Based on expected admissions to the treating institution over the recruitment period, it is expected that this will provide an estimated recruitment pool of 300 eligible participants and sample size of approximately 250 participants. This proposed sample size allows for variation in EVP, missing data and participants lost to follow-up.

Patients undergoing lumbar spinal surgery will be identified from the surgical lists. All eligible patients will be provided with an information pack containing a participant information statement, consent form, withdrawal of consent form and baseline outcome measures. The research physiotherapist will contact potential participants during the week prior to surgery to confirm eligibility and respond to any questions. Written consent will be obtained from all participants. Consent forms and baseline outcome measures will be collected from participants following admission to hospital. Demographic data and information about the surgical procedure will be collected from the participant and patient records during admission.

Following surgery, all participants will be fitted with an activPAL3 accelerometer (PAL technologies) to be worn for the first seven post-operative days, commencing the morning after the day of surgery. As per the manufacturer instructions, the accelerometer will be fixed to the upper thigh using a waterproof transparent Tegaderm dressing. This can then remain in place for the seven-day monitoring period, with a daily review to check for discomfort or irritation. This method of fixing the accelerometer to the thigh eliminates the need for participants to remove and apply the monitoring device for showering and sleeping, it does not require participants to wear a waist band or belt that would sit across the site of the lumbar surgery.

Where participants are discharged during the seven-day monitoring period they will be provided with information regarding the use and removal of the accelerometer, and a reply paid envelope to return the accelerometer to the researcher.

Six-month follow-up

At 6 months following surgery participants will be sent follow-up outcome measures, to be returned to the researchers by mail.

All participants will receive routine inpatient physiotherapy management. As part of routine management participants are encouraged to walk at least 3 times daily over a comfortable distance, increasing both the frequency and distance as able. An exercise program is also commenced within the first 3 days following surgery, and includes activation of deep core muscles in a supine position, exercises to gently increase range of motion including lumbar rotation and neural slides, and lower limb strengthening. A single researcher will conduct all participant communication, measurement, data collection and application of accelerometers.

Outcome measures

An outcome assessment timeline and summary of assessment tools used is provided in Table 1.

Dependent variable

The primary dependent variable will be self-reported function. This will be measured using a Modified Oswestry Disability Questionnaire (ODQ) [30] and the physical component summary (PCS) of the SF-36 (version 2) [31, 32]. Back and leg pain intensity using the numeric pain rating scale (0–10) (NPRS) [33] will be recorded as

Table 1 Timeline of outcome assessment

Pre-operative (baseline)	
Baseline demographics:	Age, sex, smoking status, height, weight, diabetic history
History of back/leg symptoms:	Duration of symptoms, neurological deficit
Physical function:	ODQ, SF-36
Pain:	Back and leg pain (NRPS)
Physical activity:	IPAQ-SF
Psychological status:	Depression (PHQ-9), anxiety (GAD-7)
Post-operative (days 1–7):	
Surgical procedure:	Decompression, discectomy, fusion; single or multi-level
Accelerometry:	Time spent walking, step count, time spent in sedentary and active postures, number of walks
Pain:	Back, leg and wound pain (NRPS)
Supervised walking:	Patient/physiotherapist reported
Post-operative complications:	Complications requiring medical intervention and/or limit walking time
Post-operative (6 months):	
Physical function:	ODQ, SF-36
Patient satisfaction:	5 point likert scale
Post-operative complications:	Complications requiring medical intervention

secondary dependent variables. The ODQ, SF-36 and the NPRS are all validated and recommended for use within the back pain population [34], and are widely used in spinal surgery research. The modified ODQ substitutes kilometres for miles to estimate walking distance, and has been validated in the Australian population [30]. The relationship between post-operative walking and each of the four dependent variables will be analysed individually.

Independent (predictor) variable

The predictor variable to be used in data analysis will be the total time spent walking (recorded as total time performing stepping activity) over the first seven post-operative days. This data will be recorded using an activPAL3 accelerometer and downloaded using software provided by PALtechnologies. The activPAL3 accelerometers provide a user-friendly measure of posture and walking with robust evidence for validity and sufficient reproducibility for this study [24–26]. As the activPAL3 accelerometer is worn on the thigh, the accuracy of the monitor is not reliant on arm swing and is not expected to vary if participants are using a gait aid.

Independent (confounding) variables

Data will be collected for variables where there is either evidence to suggest they influence outcome following lumbar spinal surgery, or there is or strong theoretical rational for their inclusion. This will include age, gender, current smoking status [14, 15], obesity [14, 18], diabetes [14, 16, 17], depression [19, 20], duration of pain/symptoms [35], neurological deficit [14], anxiety, pre-operative activity, pre-operative mobility, surgical procedure, multi-level surgery, and pre-operative function.

Depression will be assessed using the Patient Health Questionnaire Depression Scale (PHQ-9), using a cut off score of ≥10 [36]. The PHQ-9 is a short, valid and reliable measure of depression, and has been recommended for use within the chronic back pain population [37]. Anxiety will be scored using the Generalised Anxiety Disorder 7-item Scale (GAD-7), using a cut off score of ≥10 [38]. The GAD-7 is a brief, seven question scale used to screen for, and assess the severity of anxiety. It has been validated in the general population [38]. Neurological deficit will be assessed by asking the participant if he/she is aware of any changes to the sensation or strength in their affected lower limb. This level of information is deemed appropriate for this study, as any sensory or motor deficit that the participant is unaware of is unlikely to have an impact on functional ability. Pre-operative activity will be assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF) [39, 40]. The IPAQ-SF is a brief, reliable seven item questionnaire that requires participants to report on physical activity undertaken over the previous seven day period [39, 40]. Physical activity is categorised into low, moderate and high activity levels. As it is expected that the majority of participants will report either low or moderate activity levels, the two categories of low and moderate/high activity levels will be used for data analysis. Baseline ODQ score will be used as a measure of pre-operative function. Pre-operative mobility will be categorised based on the response to Section 4 (Walking) on the ODQ. Participants will be categorised as having limited mobility if they score 3 or more - unable to walk more than 500 m, require a walking aid, or are confined to bed.

Post-operative activity profile

A seven day activity profile summarising the amount of time spent in sedentary and active postures, time spent walking, a step count, and the number of walks will be generated using the data downloaded from the activPAL3 accelerometers.

Factors associated with time spent walking immediately following surgery

Additional data will be collected on a daily basis regarding post-operative back, leg and wound pain intensity (NRPS), the need for supervision while walking, and surgical/medical complications. Reported complications will include events where the participant requires medical intervention in addition to routine post-operative care, and events that limit activity (for example, symptomatic hypotension, analgesia-induced nausea). This information will be sourced from the patient, ward staff, and patient notes. In cases where participants are discharged from the inpatient facility prior to completing the monitoring period they will be asked to record this information daily, which will then be returned to the researchers with the accelerometer following the completion of the monitoring period.

At six months, participants will be asked to report on overall satisfaction with the results of the surgery, scored on a five point likert scale. They will also be asked to describe any post-operative complications experienced after the seven day monitoring period. This will include any event directly related to the surgical procedure requiring medical intervention in addition to routine follow-up care.

Data analysis

Baseline demographics of the study population will be analysed using descriptive statistics.

Relationship between time spent walking and outcome

Multivariable logistic regression analysis will be used to investigate the relationship between the time spent walking in the first week after surgery and outcome at six months using SPSS software. The dependent variable in the logistic

Table 2 MCID and SCB thresholds

Outcome measurement tool	MCID (points change)	SCB (points change)
ODQ	10	18.8
SF-36 (PCS)	4.9	6.2
NPRS (back)	2	2.5
NRPS (leg)	2	2.5

regression model will be the change in score on the ODQ, SF-36 (PCS), NRPS (back) and NRPS (leg) between baseline and six months. The change in scores on the ODQ, SF-36 (PCS) and NRPS will be dichotomised based on the threshold required to demonstrate a substantial clinical benefit.

Thresholds required to meet the minimum clinically important difference (MCID) have been identified for the ODQ, the SF-36 (PCS) and the NPRS [41] (Table 2). In addition, thresholds required to obtain a substantial clinical benefit (SCB), where patients report a major improvement in symptoms, have been defined for the ODQ, SF-36 (PCS) and NRPS in the lumbar fusion population [42] (Table 2). For the purpose of this study it has been assumed that SCB following lumbar fusion surgery provides a fair estimate of substantial clinical benefit following lumbar surgery in general. These thresholds allow the change in scores to be categorised as minimal improvement (below MCID threshold), moderate improvement (above MCID threshold, below SCB threshold) and substantial improvement (SCB threshold or greater).

As all participants in this study are undergoing surgery with the aim of improving pain and physical function, it expected that the majority of participants in this study will report an improvement in scores above the MCID threshold. Therefore the SCB threshold will be used to analyse the impact of walking time on outcome (minimal/moderate improvement compared to substantial improvement). For each of the four dependent variables a multivariable logistic regression model will be generated comparing participant outcome relative to the SCB threshold.

With the exception of pre-operative function and surgical procedure, all confounding variables will be dichotomised (Table 3).

Bivariate analyses will be carried out to assess the association between each confounding variable and each outcome measure. The variables that have an independent association with outcome will be included in the final regression model. Analysis of correlation between the independent variables will be carried out to assess for multicollinearity. Where variables are highly correlated, either the more relevant variable or the variable with the more complete data set will be retained in the final regression model [43].

Missing independent variable data will be managed based on the quantity of missing data per participant and per variable. In the case of missing or incomplete accelerometry data, participants will be removed from analysis where three or more days of recordings are missing. In the case of one to two days of missing data, the time spent walking each day will be estimated based on the mean daily walking time of the total sample population. Comparisons will be made between the characteristics of participants with and without missing data to ensure minimisation of bias [43]. The underlying assumptions of the model will be assessed using the SPSS software "goodness of fit" testing.

Table 3 List of independent variables and classification for statistical analysis

	Classification				
1. Post-operative activity	Time spent walking (minutes)				
2. Age	1. < 65 years	2. ≥ 65 years			
3. Gender	1. Male	2. Female			
4. Current smoking status	1. Non-smoker	2. Smoker			
5. Obesity	1. BMI < 30	2. BMI ≥ 30			
6. Diabetes	1. Not diabetic	2. Diabetic			
7. Depression	1. PHQ-9 < 10	2. PHQ-9 ≥ 10			
8. Anxiety	1. GAD-7 < 10	2. GAD-7 ≥ 10			
9. Duration of pain/symptoms	1. < median (months)	2. ≥ median (months)			
10. Neurological deficit	1. No deficit	2. Neurological deficit			
11. Pre-operative activity	1. IPAQ-SF - Mod/high	2. IPAQ-SF - low			
12. Pre-operative mobility	1. ODQ (section 4) < 3	2. ODQ (section 4) ≥ 3			
13. Surgical procedure	1. Decompression	2. Disc surgery	3. Fusion		
14. Multi-level surgery	1. Single level surgery	2. Multi-level surgery			
15. Preoperative function (ODQ%)	1. 0–20	2. 21–40	3. 41–60	4. 61–80	5. 81–100

Bivariate analysis will be used to examine the association between post-operative walking time, and both patient satisfaction and post-operative complications as reported at six months.

Post-operative activity profile
Descriptive statistics will be used to analyse post-operative activity.

Factors associated with post-operative walking time
Bivariate analysis will be used to examine the association between the total time spent walking, and pre-operative mobility, function and physical activity, post-operative back, leg and wound pain, post-operative complications and the need for supervision while walking.

Discussion
The findings from this research will assist physiotherapists to identify patients who are expected to have either very good or poor post-operative outcomes based on their activity levels immediately following surgery, and inform physiotherapists about whether increasing activity should be a focus of post-operative rehabilitation. This will help to guide patient management during the inpatient phase, by identifying patients who are at risk of poorer outcome due to limited walking time. These patients may benefit from ongoing rehabilitation and outpatient physiotherapy services. This information will also provide a foundation for further research into interventions designed to optimise post-operative activity such as patient education resources, improved monitoring and management of post-operative pain, or the provision of additional physiotherapy sessions for patients who require supervision while walking.

Abbreviations
EVP: Events per predictor variable; GAD-7: Generalised Anxiety Disorder 7-item Scale; IPAQ-SF: International Physical Activity Questionnaire Short Form; MCID: Minimum clinically important difference In addition; NPRS: Numeric pain rating scale; ODQ: Oswestry Disability Questionnaire; PHQ-9: Patient Health Questionnaire Depression Scale; SCB: Substantial clinical benefit; SF-36 (PCS): SF-36 physical component summary; SVPHF: St Vincent's Private Hospital, Fitzroy

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Availability of data and materials
Not applicable.

Authors' contributions
All listed authors (SG, JM, MD) have made substantial contributions to the study design, and the drafting and revision of the manuscript. All authors have given final approval for publication.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

Ethics approval and consent to participate
Ethics approval has been obtained from the St Vincent's Hospital (Melbourne) Human Research Ethics Committee (LRR 098/15) and the La Trobe University Ethics Committee. Written consent will be obtained from all participants.

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Chapter 6: Physical activity patterns of patients immediately after lumbar surgery

This chapter presents the findings of a component of the study protocol outlined in Chapter 5. This study aimed to describe patient activity patterns in the first week after surgery, and to identify factors that may influence the amount of activity patients undertake in the first post-operative week.

The research questions addressed in this study were:

1. What proportion of time do patients spend performing active tasks (standing and walking) compared to sedentary behaviour (sitting and lying) in the week following lumbar spinal surgery?
2. Is the amount of time spent walking in the first post-operative week influenced by participant characteristics, post-operative pain or function, or factors specific to the surgical procedure and hospital admission?

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The Figures and Tables referred to in the text are included as an appendix (Appendix VII).

Physical activity patterns of patients immediately after lumbar surgery

Abstract

Purpose

To describe the physical activity patterns of patients in the first week after lumbar surgery, and to investigate factors that potentially limit walking time early after surgery.

Materials and Methods

Adults undergoing lumbar decompression, discectomy and/or fusion surgery (N=216, mean age 62 years, SD 13.9) were invited to participate. Walking time and step count were recorded for the first seven post-operative days, using an ActivPAL accelerometer. Participants recorded daily pain scores, supervision requirements while walking, and any complications that prevented walking.

Results

On the first post-operative day, participants spent an average of 17 minutes (SD 20) walking, by Day 6, participants spent an average of 53 minutes (SD 38) walking. Participants who reported minor post-operative complications had a significantly lower step count than those without complications (p<0.01). A lower step count was associated with a longer time to achieve independent mobility (r=-0.60, 95% CI -0.68 – -0.50), and a longer hospital admission (r=-0.70, 95% CI -0.76 – -0.63).

Conclusions

This study found that patients walk for less than an hour a day over the week after lumbar surgery. Further research is required to investigate whether intervention designed to increase walking time improves post-operative activity and longer-term patient outcome.

Background

Low back pain is the current leading cause of global disability [1]. Where low back pathology is associated with a neurological deficit that is non-responsive to conservative management, surgical intervention may be indicated. The rate of lumbar surgery has increased considerably over the last two decades [2,3], and as the incidence of low back pain and associated disability increases with the aging population [1] it is likely the number of surgeries performed will continue to rise. While there has been considerable advancement in spinal surgery techniques there is limited evidence to guide peri-operative rehabilitation practices, particularly in the first four to six weeks after surgery [4,5].

After lumbar surgery, the majority of patients are seen by a physiotherapist in the immediate post-operative period, with early rehabilitation focusing on achieving independent mobility and encouraging regular walking [6-8]. Promoting early and increased walking is now standard practice in Australian hospitals for the majority of patient groups, with a growing evidence base linking increased mobility to reduced post-operative complications, reduced length of stay, and improved longer-term outcomes [9].

The benefits of regular physical activity in the healthy adult population have been well established, with international guidelines recommending adults complete a minimum of 150 minutes per week of moderate intensity exercise to maintain cardiovascular health and reduce the risk of chronic disease [10,11]. However, research indicates that worldwide, healthy adults consistently perform considerably less physical activity than the guidelines recommend [12-14]. This trend is amplified in patients after lumbar surgery with only a quarter achieving the recommended minimum of 150 minutes per week of moderate intensity activity up to two years after surgery [15].

The time spent in physical activity tasks in the first week after surgery, and the factors that may contribute to low long-term activity levels are yet to be explored. Despite the focus on walking in early post-operative rehabilitation, there is little knowledge about normal activity patterns acutely after surgery, and very little evidence to guide the design of early post-operative walking programs [3,5]. Research has shown that activity levels are generally low in hospital inpatient populations [16], and this low activity level continues in early the sub-acute period after lumbar surgery [17]. To further understand the trajectory of resuming physical activity for lumbar surgery patients it is important to quantify normal activity patterns immediately after surgery, and to explore the factors that may limit walking in this population. This information can then be used to design safe and effective walking programs that commence early after surgery, working towards achieving the minimum recommended physical activity levels.

This primary aim of this study is to describe the physical activity patterns of patients in the first week after lumbar spinal surgery. The secondary aim is to investigate the association between step count and factors that potentially limit waking, including participant characteristics and pre-operative factors, post-operative pain and function, and factors specific to the surgical procedure and hospital admission.

Methods

Study design

A cross-sectional study design was used to examine the activity patterns of patients the week after lumbar spinal surgery. Ethics approval was obtained from the St Vincent's Hospital Melbourne Human Research Ethics Committee (Reference: LRR 098/15).

Participants

Participants were recruited from St Vincent's Private Hospital Melbourne (SVPHM) between April and November 2016. Patients aged 18 years and over undergoing surgery for the management of a lumbar spinal condition (disc prolapse, degenerative disc disease, spinal stenosis or degenerative spondylolysthesis) were identified from the admission and theatre lists of the 11 neurosurgeons that performed spinal surgery at SVPHM. Patients were excluded if their surgery was for the management of spinal tumours or fractures, they had a cognitive impairment or were unable to provide informed consent, or had a secondary pre-existing neurological or musculoskeletal disorder that limited walking.

Procedure

Prior to surgery, potential participants were contacted to confirm eligibility and explain the study aims and procedures. Participants completed pre-operative measures of self-reported pain and function including the Numeric Pain Rating Scale (NPRS) for back and leg pain intensity (0-10) [18], the Oswestry Disability Questionnaire (ODQ) [19], the SF-36 (Version 2) [20], and the International Physical Activity Questionnaire Short Form (IPAQ-SF) [21,22]. The presence of a pre-operative mobility restriction was determined if participants responded with a score of ≥ 3 in Section 4 of the ODQ (unable to walk more than 500m, or requires a stick, crutches or other support). Demographic data, details of the surgical procedure, discharge day and discharge destination were obtained from the hospital admission records. For the first seven post-operative days, participants completed a daily questionnaire that included a back, leg and wound pain score (NRPS), whether they required supervision while walking, and whether they experienced any complications that limited walking. Written informed consent was obtained from all participants. All participant recruitment and data collection were completed by a single researcher.

Daily activity patterns and step count were recorded using an ActivPAL3 accelerometer (PAL Technologies, Glasgow, Scotland). The ActivPAL3 has previously been shown to provide an accurate measure of step count in patients immediately after lumbar surgery [23]. Recording began at 8am on the morning after surgery and continued for seven days, stopping at 8am on the eighth post-operative day. The accelerometer was attached to the anterior thigh with a waterproof dressing and remained in place for the seven-day monitoring period. The monitor site was reviewed daily to ensure constant adhesion and to check for skin irritation, and the dressing was changed as required. On discharge, participants were provided with instructions for ongoing care and removal of the monitor, and a reply-paid envelope to return the monitor and daily questionnaire to the researchers following completion of the monitoring period.

All participants were seen by a physiotherapist on the first post-operative day. Routine physiotherapy consisted of advice about post-operative restrictions and return to physical activity, gait assessment and provision of a gait aid as required, and a low impact exercise program (including trunk and lower limb strengthening, and lumbar stretches through pain free range of motion). Participants were encouraged to walk on the first post-operative day and increase their walking distance on each subsequent day. Post-operative sitting and movement restrictions varied based on individual surgeon protocols. Participants did not routinely wear a post-operative lumbar brace. Participants were discharged from the in-patient physiotherapy service once they were walking independently, were independent with their exercise program, and had been provided with all relevant post-operative advice and education. Participants continued to wear the accelerometer for the full seven-day monitoring period, regardless of whether they had been discharged from physiotherapy, or from the acute hospital ward.

Data analysis

Data were analysed using SPSS version 24 (IBM, New York, USA). Data recorded by the ActivPAL3 were downloaded using software provided by PAL Technologies. The software provided the raw accelerometry data for each participant: the number of steps detected and a summary of the time spent sedentary, standing and walking. The raw data were analysed to identify walking episodes of (i) longer than one minute, (ii) longer than five minutes, and (iii) longer than ten minutes throughout the seven-day period. A walking episode was defined as a period of activity that commenced with at least five steps, included no sitting or lying periods, and concluded with at least five steps. A walking episode was excluded when participants had a period of more than 15 seconds of consecutive standing without steps over a one-minute period, or a period of more than 30 seconds of consecutive standing without steps over a five and ten minute and period.

Participant activity patterns were described using (i) the hourly and daily and step count, (ii) the time spent in stepping, standing, and sedentary tasks, and (iii) the number of walking episodes completed greater than one, five and ten minutes long.

To investigate the association between step count and factors that potentially limit walking, (i) Pearson's Correlation Coefficient was used to investigate a relationship between step count and continuous measures (age, pre-operative pain severity, ODQ, SF-36), (ii) Spearman's Rho was used to investigate a relationship between step count and ordinal measures (duration of pre-operative pain, number of days requiring supervision while walking), and (iii) independent t-tests were used to analyse the between group differences for categorical measures (sex, pre-operative mobility, pre-operative activity, surgical procedure, number of vertebral levels, and post-operative complications).

Results

A total of 315 patients were assessed for eligibility over the seven-month recruiting period. Nine patients did not meet the eligibility criteria (four were unable to provide consent due to limited English, and five had a secondary neurological or musculoskeletal disorder that limited their walking), and eighteen declined to participate. A total of 288 patients were eligible to take part in the trial. Of these, 39 were unable to complete activity monitoring as there was no monitor available immediately after their surgery. A further 33 participants were excluded due to a lost monitor (N=14), faulty monitor (N=7), low battery (N=3), inaccurate monitor set up (N=4) or incomplete monitoring period (N=5). On initial analysis of the seven-day activity patterns, it was apparent that 15% (N=33) of participants did not wear the monitor on the seventh day, and a further 19% (N=42) removed the monitor early on day seven. To eliminate any systematic error arising as a result of incomplete data recording, data recorded on the seventh day was removed from the analysis.

A total of 216 participants were included in the study. The mean age was 62 (SD 13.9), 51% (N=111) were female (Table 1). Post-operatively, 55 (26%) of participants complained of minor complications including nausea, vomiting, dizziness, hypotension, low haemoglobin requiring transfusion, infection (not at the surgical site), cardiac arrhythmia, lethargy, confusion and migraine (Table 2). Of these, nausea, vomiting and dizziness were the most frequently reported.

Activity Profile

Over the entirety of the six-day monitoring period, participants spent an average of 3% of their time walking (Table 3). On Day 1, participants spent 1% of the time walking, 6% of the time standing and 93% of the time sedentary. By Day 6 participants spent 4% of the time walking, 12% of the time standing, and 84% of the time sedentary (Figure 1). Daily activity increased from an average of 1141 steps (SD 1404) or 17 minutes (SD 20) on Day 1, to an average of 3823 steps (SD 2950) or 54 minutes (SD 38 minutes) on Day 6 (Figure 2, Table 3). There was a consistent trend for increased activity in the morning, with the highest hourly step count recorded between 9am and 11am on each day (Figure 2).

Seventy three percent (N=154) of participants completed a walk of one minute or longer the first day after surgery, and 98% (N=212) had completed a walk of one minute or longer by the end of day six. Over the six days, 83 participants (38%) completed at least one walk of ten minutes or longer. Of the 83 participants who completed a ten minute walk at least once, 53 (64%) did so on more than one day.

Analysis of step count in relation to participant factors

Younger age (r=-0.35, 95%CI -0.46 – -0.22), shorter duration of pre-operative pain (r=-0.30, 95%CI -0.42 – -0.17), and less severe pre-operative back pain (r=-0.21, 95%CI -0.33 – -0.08) were associated with a higher step count in the first six days after surgery. Participants undergoing lumbar discectomy had a significantly higher step count than those having decompression (t=3.46, p<0.01) or fusion surgery (t=5.12, p<0.01), and participants undergoing single level surgery had a higher step count than those undergoing multi-level surgery (t=3.59, p<0.01). Higher step count was associated with experiencing no minor post-operative complications (t=4.02, p<0.01), earlier achievement of independent walking (r=-0.60, 95% CI -0.68 – -0.51), and less severe post-operative back (r=-0.27, 95%CI -0.32 – -0.22), leg (r=-0.12, 95%CI -0.18 – -0.06) and wound pain (r=-0.20, 95%CI -0.25 – -0.14) (Tables 4 and 5).

Discussion

This is the first known study to describe walking time and physical activity patterns immediately after lumbar surgery. This study adds to the existing knowledge base, and combined with previous research creates a more comprehensive picture of normal post-operative activity patterns. These findings demonstrated a progressive increase in walking time over the first six days after surgery. Previous research indicates that the progressive increase in step count continues over the first three post-operative months [17], however it is likely that this increase plateaus sometime between three and twelve months [24]. Additional evidence suggests that physical activity levels are still considerably lower than those recommended by the World Health Organisation [11] two years after lumbar surgery [15]. Collectively, these results may be used to guide expectations for normal recovery of physical activity from early after lumbar surgery, and aid clinicians in designing post-operative walking programs based on population norms.

Although participants in this study spent the majority of their time in sedentary positions, they were considerably more active than other previously studied hospital inpatient groups [16, 25-27]. The relatively higher activity levels after lumbar surgery may reflect differences in the observed patient populations, such as frailty and medical co-morbidities, or possibly the changing culture of the hospital environment over the intervening years towards promoting increased patient activity. However, collectively these studies indicate that hospital inpatients spend the majority of time in sedentary positions. Combined with the growing evidence base linking immobility to hospital acquired complications and increased length of stay [9], the results from this study support the need to address low activity levels across hospital inpatient populations.

This study identified several factors that may be used to inform rehabilitation protocols early after lumbar surgery. This may include providing older patients, those with more severe pre-operative low back pain, and those undergoing a fusion procedure (all associated with a lower activity level) with an intensive rehabilitation program that is specifically designed for these cohorts to increase walking from early after surgery. Conversely, younger patients or those undergoing laminectomy or discectomy may require less intensive rehabilitation. Following surgery, walking was limited in patients with severe post-operative pain, and post-operative symptoms such as dizziness and nausea. This result was unsurprising, and emphasises the need for effective peri-operative patient management to minimise pain and other symptoms that prohibit activity. In addition, walking time was also limited in patients who required supervision while walking. This suggests that early post-operative protocols may need to focus on multidisciplinary interventions designed to promote independence and increase activity in patients who require supervision while walking.

Study Limitations

There are some limitations of this study that need to be considered. Participants were aware their activity was being monitored, which may have influenced walking time. To mitigate this, the activity monitors used provided no feedback to participants. A limitation of the accelerometer used was that the ActivPAL3 software did not provide data on time spent performing continuous stepping activity (individual walk duration) or METs for periods of less than an hour in duration. It was therefore not possible to calculate participant activity levels based on continuous walking time or METs for this population group, where walking time and stepping activity was in typically short bouts. As intervention and advice regarding physical activity varies following lumbar surgery [6-8] it is likely that post-operative activity levels vary across hospitals, therefore these results may not be generalizable.

There are several other factors that may potentially limit walking time early after lumbar surgery that were not measured in this study, that need to be taken into consideration when interpreting these results. The negative impact of psychosocial factors on post-operative recovery have been well documented, including depression and anxiety [28], fear avoidance [29] and catastrophization [30]. It is possible that the presence of these factors may influence post-operative walking time, further study is required to investigate this possibility.

Conclusion

This study found that on average lumbar surgery patients walk for less than an hour a day over the week after lumbar surgery. A lower step count was associated with fusion or decompression surgery, the experience of minor post-operative complications, and requiring supervision while walking for a longer period of time. A lower step count was also associated with a longer acute hospital admission and a higher admission rate to inpatient rehabilitation. Further research is required to investigate whether physiotherapy intervention targeted towards increasing walking early after surgery, increases longer term activity levels or improves patient outcomes.

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6.1. Addendum to Chapter 6: Post-hoc analysis of participant discharge variables

In addition to the variables presented in the published study in Chapter 6, data were also collected that described participants post-operative length of stay and discharge destination. The median day of discharge was on the 4th post-operative day (IRQ 2-5 days) (Table 6.6). Just over half of all participants were discharged home (N=113, 52%), with the remainder discharged to inpatient rehabilitation (N=103, 48%) (Table 6.7). Participants who went directly home had a significantly shorter length of stay in the acute hospital setting than those who went to rehabilitation (p<0.01): the median day of discharge for participants who went directly home was on the 3rd post-operative day (IRQ 2-4 days), while the median day of discharge for participants who were discharged to inpatient rehabilitation was on the 5th post-operative day (IRQ 3-6 days).

An earlier discharge from the acute hospital setting was associated with a greater step count in the first six days after surgery (r=-0.70, 95%CI -0.76 - -0.63, p<0.01). Further analysis revealed that participants in the lowest quartile for total step count had a median post-operative length of stay three times greater than participants in the highest quartile (Table 6.6, Figure 6.2).

Participants who were discharged home had a significantly higher mean total step count (21923 steps, SD 12540) than participants who were discharged to inpatient rehabilitation (9699 steps, SD 8917) (p<0.01). Eighty-five percent (N=46) of participants in the lowest quartile for total step count were discharged to rehabilitation, compared to 85% (N=46) in the highest quartile being discharged home (Table 6.7, Figure 6.3).

Overall, these results indicate that participants with a higher step count in the first six days after lumbar surgery had a shorter post-operative length of stay, and were more likely to be discharged home. Conversely, those with a lower step count were more likely to have an extended period in the acute hospital setting, followed by admission to inpatient rehabilitation. Low activity levels after surgery may be a broad indicator of patients who are more likely to have a prolonged recovery, which in turn increases length of stay and likelihood of being discharged to rehabilitation rather than home. It is also possible that walking ability in the early post-operative period is a key factor that influences decision making of health professionals with regards to a patient's discharge timing and destination. There are a number of additional factors, such as pre-operative walking ability and co-morbidities, that potentially confound this relationship between step count, length of stay and discharge destination. These factors are not accounted for in this analysis and therefore need to be considered when interpreting these results. These findings however do provide insight into the possible impact of low activity levels on short term discharge parameters, and may be used to guide future research in this field.

Table 6.1. Post-operative length of stay based on total step count over the first six days after surgery

	Day of discharge based on total step count (Median (IRQ))				
	Total	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Day of discharge (days after surgery)	4 (2-5)	6 (4-7)	4 (3-5)	3 (2-4)	2 (2-3)

Note: the 1st Quartile represents the 25% of participants with the lowest total step count, the 4th Quartile represents the 25% of participants with the highest total step count.

Figure 6.1. Post-operative length of stay based on total step count over the first six days after surgery

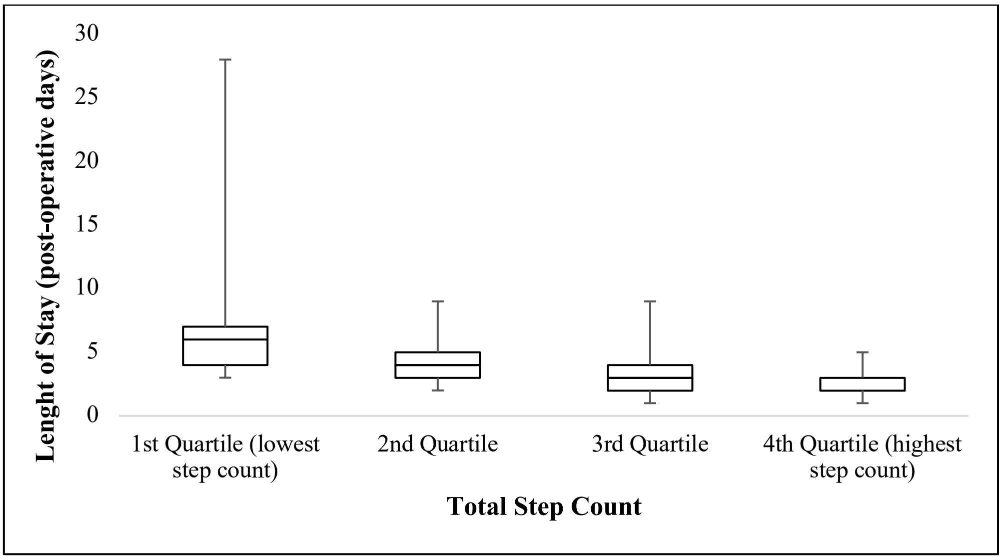
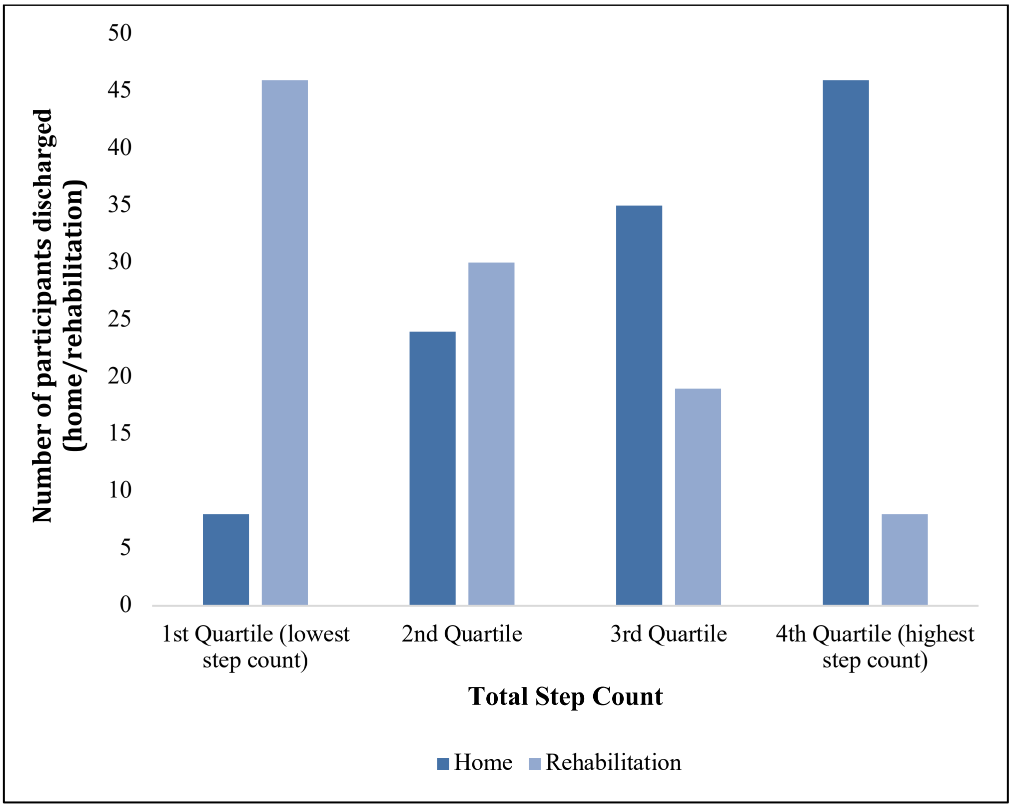


Table 6.2. Discharge destination based on total step count over the first six days after surgery

	Discharge destination based on total step count (N(%))				
	Total	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Home	113 (52%)	8 (15%)	24 (44%)	35 (65%)	46 (85%)
Rehabilitation	103 (48%)	46 (85%)	30 (56%)	19 (35%)	8 (15%)

Note: the 1st Quartile represents the 25% of participants with the lowest total step count, the 4th Quartile represents the 25% of participants with the highest total step count.

Figure 6.2. Discharge destination based on total step count over the first six days after surgery



Chapter 7: Predictors of substantial improvement in physical function six months after lumbar surgery: is early post-operative walking important? A prospective cohort study

This chapter presents the final component of the study protocol outlined in Chapter 5, which aimed to establish the relationship between time spent walking in the first week after lumbar surgery and recovery of physical function at six months.

The research questions addressed in this study were:

1. Does the amount of walking in the first week after lumbar surgery predict recovery of physical function at six months?
2. Does the amount of walking in the first week after lumbar surgery predict improvement in leg or back pain at six months?

This study is presented in its published format: Gilmore SJ, Hahne AJ, Davidson M, McClelland JA. (2019). Predictors of substantial improvement in physical function six months after lumbar spine surgery: is early post-operative walking important? A prospective cohort study. *BMC Musculoskeletal Disorders*. 20(1):418-26.

The Supplementary Tables referred to the published text are included as an appendix (Appendix VIII).

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RESEARCH ARTICLE

Open Access

Predictors of substantial improvement in physical function six months after lumbar surgery: is early post-operative walking important? A prospective cohort study

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Abstract

Background: Resuming walking after lumbar surgery is a common focus of early post-operative rehabilitation, however there is no knowledge about whether increased walking is associated with better functional outcomes. This study aimed to determine whether time spent walking in the week after lumbar surgery, along with co-morbidities, pre-operative pain duration, pre-operative physical activity or function, or surgical variables predict substantial improvement in physical function six months after lumbar surgery.

Methods: A prospective cohort study design was utilized. Participants undergoing lumbar surgery (discectomy, decompression, fusion) were recruited between April and November 2016. Predictor variables were collected pre-operatively (age, sex, smoking status, obesity, diabetes, depression, anxiety, pre-operative pain duration, neurological deficit, physical activity levels, mobility restriction, function) and early post-operatively (post-operative walking time, surgical procedure, single/multi-level surgery). Outcome variables (physical function, back pain and leg pain severity) were measured pre-operatively and six-months post-operatively. Logistic regression analysis was used to establish prediction of substantial improvement in outcome at six months.

Results: Participants ($N = 233$; 50% female; age 61 ($SD = 14$) years) who walked more in the first post-operative week were more likely to have substantially improved function on the Oswestry Disability Questionnaire at six months (OR 1.18, 95%CI 1.02–1.37), as were participants with < 12 months pre-operative pain (OR 2.71, 95%CI 1.28–5.74), and those with lower pre-operative function (OR 4.02, 95%CI 2.33–6.93). Age < 65 years (OR 2.36, 95%CI 1.14–4.85), and < 12 months pre-operative pain (OR 3.52 95%CI 1.69–7.33) predicted substantial improvement on the SF-36 Physical Component Summary. There were no significant predictors for substantial improvement in either leg or back pain.

Conclusions: Walking time in the week after lumbar surgery is one of several predictors of substantial improvement in function at six months. Further research is required to determine whether intervention designed to increase walking early after lumbar surgery results in improved longer-term recovery of function.

Trial registration: Australian New Zealand Clinical Trials Registry (ANZCTR), registration number 12616000747426. Retrospectively registered on the 7th of June 2016.

Keywords: Physical therapy, Physical activity, Lumbar surgery, Lumbar fusion, Discectomy, Laminectomy

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Background

The number of surgical procedures performed for the management of lumbar spinal conditions has increased considerably over the previous two decades [1–3]. While surgical techniques have advanced over this time, whether surgical intervention leads to improved patient outcome remains inconclusive [4–6], with up to 40% of patients reporting no improvement in symptoms following surgery [7]. It may be possible to improve the success of surgical intervention through rehabilitation programs specifically designed to optimise post-operative recovery. However, there has been very little research investigating the effectiveness of rehabilitation after lumbar spine surgery [8, 9].

The majority of patients undergoing lumbar surgery in Australia and the UK are seen by a physiotherapist during their hospital admission. While the focus of early rehabilitation is commonly on resuming walking [10–12], walking time in the post-operative period has not previously been evaluated for its association with longer term outcomes in people undergoing lumbar surgery. A number of other factors have been shown to predict outcomes following lumbar surgery including age [13, 14], sex [13, 15], smoking status [16] obesity [13], diabetes [17], depression [18], anxiety [13], symptom duration [15], and pre-operative disability [13, 14, 16]. To further the current understanding about recovery after lumbar surgery is important that additional potential predictive factors, such as walking time in the immediate post-operative period, are evaluated relative to these existing predictors of surgical outcome.

Objective measurement using accelerometry is a valid [19] and increasingly common method of quantifying walking and physical activity after lumbar surgery. Recent research indicates that patients do very little walking in the first post-operative week [20], a trend that continues for up to two years after surgery [21]. It also appears that patients perform significantly less walking six months after lumbar surgery than they have the capacity to do [22], suggesting that it may be possible to increase walking time through targeted intervention. This discrepancy further supports for the need to investigate whether increased walking time is associated with better post-operative outcomes.

The aim of this study, as described in the published protocol [23], was to investigate which variables predict improvement of a) physical function and b) back and leg pain severity six months after lumbar spinal surgery, with a focus on walking time early after surgery.

Methods

Study design

A prospective cohort study design was used. Ethics approval was obtained from the St Vincent's Hospital Melbourne Human Research Ethics Committee (Reference: LRR 098/15).

Participants

Participants were recruited from St Vincent's Private Hospital Melbourne (SVPHM). Patients aged 18 years or older, admitted for surgical management of a disc prolapse, degenerative disc disease, lumbar spinal stenosis and/or degenerative spondylolysthesis were invited to participate. Patients were excluded if surgery was for the management of fractures or tumours, if they were unable to provide informed consent, or if they had a co-existing neurological or musculoskeletal condition resulting in impaired physical function. There were no exclusion criteria based on the duration or nature of pre-operative symptoms.

Procedure

Potential participants were identified from the neurosurgical theatre lists of the 11 neurosurgeons performing spinal surgery at SVPHM at the time of this study. Prior to surgery, the research physiotherapist informed eligible participants about the study aims and procedures, and provided them with an information pack and pre-operative outcome measures. Written informed consent was obtained from all individual participants included in the study.

Post-operatively, participants wore an ActivPAL3 accelerometer (PAL Technologies, Glasgow, UK) to record total walking time over the first seven post-operative days, commencing at 8 am on the morning after surgery. On discharge from hospital, participants were provided with instructions to return the monitor after the recording period was completed. Six months after surgery participants were posted follow-up outcome measures to complete, which were returned to the researchers by mail.

All participants received routine post-operative physiotherapy treatment that commenced the day after surgery. This consisted of an exercise program (trunk and lower limb strengthening and stretching exercises, individualised based on patient presentation), a bed mobility and gait assessment, and a walking program. There were no post-operative restrictions on walking, all participants were encouraged to complete regular walks over a comfortable distance, increasing the duration and frequency of walking as tolerated. All participants were advised to avoid bending, lifting, or twisting for six weeks after surgery. Five of the eleven neurosurgeons advised patients to sit for no longer then 15 min at a time for six weeks, the remaining six had no post-operative sitting restrictions.

Predictor variables

Total walking time was measured over the first post-operative week, using the ActivPAL3 accelerometer. The ActivPAL3 has been shown to be a valid measurement tool early after lumbar spine surgery (19). In addition to post-operative walking time, an additional 14 predictor variables were included, based on previous evidence to suggest a correlation with outcome after lumbar surgery, or a strong theoretical rational for their inclusion. These variables were age, sex, current smoking status, obesity, diabetes, depression, anxiety, pre-operative pain duration, presence of a pre-operative neurological deficit, pre-operative activity level, mobility, and function, the surgical procedure performed and the number of operated vertebral levels (Table 1).

Depression was assessed using the Patient Health Questionnaire Depression Scale (PHQ-9), a valid and reliable measure of depression, that has been recommended for use in the chronic back pain population [24, 25]. Anxiety was assessed using the Generalised Anxiety Disorder 7-item Scale (GAD-7), a validated measure used to screen for, and assess the severity of anxiety [26]. Neurological deficit was assessed by participant self-report of any changes to the sensation or strength in their affected lower limb. This level of information was deemed appropriate, as any sensory or motor deficit that the participant was not aware of was unlikely to impact physical function. Pre-operative activity was assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF), a self-report questionnaire assessing physical activity over the previous seven-day period [27, 28]. Pre-operative function was assessed using the pre-operative Oswestry Disability Questionnaire (ODQ) score. Pre-operative mobility was categorised into limited or not limited, based on the response to Section 4 (Walking) on the ODQ. A score of three or more indicated limited mobility - unable to walk more than 500 m, requiring a walking aid, or confined to bed.

Outcome variables

The outcome variables were described in terms of change between the pre-operative assessment, and six months after surgery. The primary outcome variable was

Table 1 Outcome and predictor variables

	Outcome measurement tool	Logistic multivariable analysis categories				
Outcome variables (Pre-operative/6 months)						
Physical function	Oswestry Disability Questionnaire (ODQ) (0–100)	1. <SCB (18.8)		2. ≥ SCB (18.8)		
	SF-36 Physical Component Summary (SF-36 PCS) (0–100)	1. <SCB (– 6.2)		2. ≥ SCB (−6.2)		
Back Pain	Numerical pain rating scale (NRPS) (0–10)	1. <SCB (2.5)		2. ≥SCB (2.5)		
Leg Pain	Numerical pain rating scale (NRPS) (0–10)	1. <SCB (2.5)		2. ≥SCB (2.5)		
Predictor variables						
Total walking time (1st 7 post-op days)	ActivPAL3 accelerometer	Hours (continuous)				
Age	–	1. < 65 years		2. ≥65 years		
Sex	–	1. Male		2. Female		
Current smoking status	–	1. Non-smoker		2. Smoker		
Obesity	Body Mass Index (BMI)	1. BMI < 30		2. BMI ≥30		
Diabetes	–	1. Not diabetic		2. Diabetic		
Depression	Patient Health Questionnaire Depression Scale (PHQ-9)	1. No depression: PHQ-9 < 10		2. Increased likelihood of depression: PHQ-9 ≥ 10		
Anxiety	Generalised Anxiety Disorder 7 Item Scale (GAD-7)	1. No anxiety: PHQ-9 < 10		2. Increased likelihood of anxiety: PHQ-9 ≥ 10		
Pre-operative pain duration	–	1. < 12 months		2. ≥12 months		
Neurological deficit	Self-report	1. No deficit		2. Sensory/motor deficit		
Pre-operative activity	International Physical Activity Questionnaire Short Form (IPAQ-SF)	1. Moderate/high activity		2. Low activity		
Pre-operative mobility	ODQ, Section 4 (restricted mobility: score ≥ 3: unable to walk more than 500 m, or requires a stick, crutches or other support)	1. Unrestricted mobility		2. Restricted mobility		
Pre-operative function	ODQ classification (%)	1. 0–20%	2. 21–40%	3. 41–60%	4. 61–80%	5. 81–100%
Surgical procedure	–	1. Decompression		2. Discectomy		3. Fusion
Number of vertebral levels	–	1. Single level		2. Multi-level		

SCB Substantial Clinical Benefit

self-reported physical function, measured using the Oswestry Disability Questionnaire (ODQ) [29] and the Short Form 36 Physical Component Summary (SF-36 PCS) (Version 2) [30]. The secondary outcome variables were back and leg pain intensity, measured using the Numeric Pain Rating Scale (NPRS) (0–10) where a higher score indicates more intense pain. The ODQ, SF-36 and the NPRS are commonly used to evaluate outcome following spinal surgery, and have all been validated in back pain populations [31].

At six months participants were also asked to report on their overall satisfaction with their post-operative recovery (Likert scale, 1–5), and if they required any ongoing medical intervention directly related to their surgical procedure.

Data analysis

Data from the ActivPAL3 were downloaded using PAL Technologies software, and analysed to identify the cumulative amount of time spent walking over the seven-day monitoring period. Descriptive analysis of the data and testing for normality were performed. The four outcome variables (ODQ, SF-36 (PCS), back pain, leg pain) were dichotomised based on the change-score thresholds required to achieve a minimum clinically important difference (MCID) [32, 33] and substantial clinical benefit (SCB) [33] (Table 2). The MCID identifies the change required on a given outcome measure to demonstrate a clinically meaningful improvement in symptoms, and is widely used in lumbar pathology research [32]. The SCB threshold however, identifies the change in outcome required to demonstrate substantial improvement in symptoms [33]. Analysis of outcome based on the MCID and SCB allows for the change in scores to be categorised as no improvement (<MCID), minimal improvement (>MCID, <SCB) and substantial improvement (>SCB). The change in physical function, back pain and leg pain over the six months were analysed using paired *t*-tests, and by using descriptive statistics to examine the proportion of participants who achieved the MCID and SCB thresholds.

Table 2 MCID and SCB thresholds

Outcome	MCID (points change)	SCB (points change)
ODQ	10	18.8
SF-36 (PCS)	4.9	6.2
NPRS (back pain)	2	2.5
NRPS (leg pain)	1.6	2.5

MCID Minimal Clinically Important Difference, *SCB* Substantial Clinical Benefit, *ODQ* Oswestry Disability Questionnaire, *SF-36* Short Form 36 Physical Component Summary, *NRPS* Numerical Pain Rating Scale

Univariate analysis of predictors of outcome

Pearson's Correlations were performed to calculate the association between the 15 predictor variables and achievement of the SCB threshold for each of the four outcome measures (ODQ; ≥18.8; SF-36 (PCS): ≥6.2; NPRS: ≥2.5) [33].

Multivariable logistic regression analysis

The predictor variables that were associated with achieving the SCB threshold at a significance level of $p < 0.1$ in the univariate analysis were entered into a multivariate logistic regression model, using a Backward Wald stepwise method. The threshold of $p < 0.1$ at the univariate stage was chosen to minimise the chance of eliminating potentially predictive variables at this stage [34]. Primary data analysis was conducted using logistic regression analysis and participants with a full data set (no missing outcome or predictor variables).

Sensitivity analysis

A secondary sensitivity analysis of the prediction models was performed by a) completing linear regression analysis of the predictor variables that were associated with change in outcome ($p < 0.1$), where change scores were continuous and not dichotomised, and b) using multiple imputation to estimate missing values in both the logistic and linear regression analyses. Comparative analysis of the pre-operative and demographic data of participants excluded due to missing data was performed using *t*-tests.

All analyses were completed in SPSS version 24 (IBM, New York, USA). The target sample size for this study was calculated based on the recommendation of five to ten outcome events per predictor variable (EPV) [35]. It was estimated that SCB would be achieved by 50% of participants on the 15 predictor variables, therefore, the minimum recommended number of participants needed to complete these analyses was 150. It was expected that a total of approximately 300 patients would be admitted for lumbar spinal surgery over the six-month recruitment period. To allow for participant exclusion, variation in EVP, missing data and loss to follow-up, the minimum recruitment target was 250 participants.

Results

Participant characteristics

A total of 233 participants consented to participate between April and November 2016. Participant characteristics are presented in Table 3, and a summary of missing data and reasons for exclusion is presented in Table 4. A further 62 participants were lost to follow-up due to incomplete activity monitor data and loss to follow-up, the remaining 171 participants (73.4%) were included in the final analysis. There was no statistically significant difference in demographic or pre-operative data between participants excluded due to incomplete activity monitor data and loss to follow-up, and those included in the final analysis (Additional file 1: Table S1, S2 in Appendix).

Preliminary analysis of the accelerometer data revealed that a high proportion of participants had removed the activity monitor during the final 24 h of monitoring. To remove the chance of systematic error as a result of incomplete data, the seventh day of monitoring has been removed from analysis. The total walking time represents the first six post-operative days.

There was a statistically significant improvement in physical function (ODQ and SF-36 PCS), back pain, and leg pain from baseline to six months after surgery (Table 5). Descriptive statistical analysis identified that the proportion of participants who achieved over and above the MCID threshold was between 64% (back pain) and 72% (SF-36 PCS). Between 51% (ODQ) and 66% (SF-36 PCS) of participants exceeded the threshold required to demonstrate a substantial clinical benefit. The average score for overall satisfaction with post-operative recovery was 4.11 (Likert scale, 1–5), with 41% of participants reporting a satisfaction score of 5 (definitely satisfied). Seventeen participants (7%) reported post-operative complications that required ongoing medical intervention (revision/further surgery $N = 10$; infection $N = 3$; deep vein thrombosis N = 1; cerebrospinal fluid leak N = 1; hematoma N = 1; reason not provided N = 1). There was no significant association between the time spent walking and post-operative complications.

Univariate analysis

Greater post-operative total walking time was correlated with achieving the SCB threshold on both the ODQ ($p = 0.05$) and the SF-36 (PCS) ($p = 0.01$) (Additional file 1: Table S3 in Appendix). In addition, female sex, pre-operative pain duration of less than 12 months, low pre-operative activity, restricted pre-operative mobility, lower pre-operative function and single-level surgery were correlated with achieving the SCB threshold on the SF-36 (PCS) ($p < 0.1$); An age of less than 65 years, no pre-operative anxiety (indicated by a negative correlation between anxiety and change in outcome, Additional file 1: Table S1 in Appendix) and a pre-operative pain duration of less than 12 months were correlated with achieving the SCB threshold on the SF-36 (PCS) ($p < 0.1$). Female sex, lower pre-operative function and single-level surgery were correlated with achieving the SCB threshold in leg pain scores ($p < 0.1$). Achieving the SCB threshold on the back pain scores was not correlated with any of the predictor variables on univariate analysis.

Table 3 Participant characteristics (N = 233)

	N	(%)
Age		
< 65	119	(51%)
≥ 65	114	(49%)
Sex		
Male	118	(51%)
Female	115	(49%)
Smoking Status		
Non-smoker	214	(92%)
Smoker	18	(8%)
Incomplete data	1	(0.4%)
Obesity		
BMI < 30	154	(66%)
BMI ≥30	73	(31%)
Incomplete data	6	(3%)
Diabetic		
No	207	(89%)
Yes	25	(11%)
Incomplete data	1	(0.4%)
Depression		
No (PHQ-9 < 10)	130	(56%)
Yes (PHQ-9 ≥ 10)	98	(42%)
Incomplete data	5	(2%)
Anxiety		
No (GAD-7 < 10)	159	(68%)
Yes (GAD-7 ≥ 10)	69	(30%)
Incomplete data	5	(2%)
Pre-operative pain duration		
< 12 months	106	(45%)
≥ 12 months	115	(49%)
Incomplete data	12	(5%)
Neurological deficit (self-report)		
No	17	(7%)
Yes	214	(92%)
Incomplete data	2	(1%)
Pre-operative activity (IPAQ-SF)		
Low	130	(56%)
Moderate	64	(27%)
High	29	(12%)
Incomplete data	10	(4%)
Pre-operative mobility (ODQ Section 4)		
Un-restricted (< 3)	113	(48%)
Restricted (≥3)[a]	120	(52%)
Pre-operative function (ODQ category)		
0–20%	15	(6%)

Table 3 Participant characteristics (N = 233) *(Continued)*

	N	(%)
21–40%	93	(40%)
41–60%	85	(36%)
61–80%	37	(16%)
81–100%	2	(1%)
Incomplete data	1	(0.4%)
Surgical procedure		
Decompression	63	(27%)
Discectomy	96	(41%)
Fusion	74	(32%)
Number of vertebral levels		
Single	175	(75%)
Multiple	58	(25%)

BMI Body mass index, PHQ-9 Patient Health Questionnaire 9; GAD-7, Generalised Anxiety Disorder 7-item scale; IPAQ-SF, International Physical Activity Questionnaire Short Form; ODQ, Oswestry Disability Questionnaire; [a]Restricted mobility: ODQ Section 4, score of ≥3 (unable to walk more than 500 m, or requires a stick, crutches or other support)

Multivariable logistic regression analysis

Greater total walking time over the first six post-operative days was predictive of substantial clinical improvement in physical function at six months (ODQ change of ≥18.8 points). For every one hour increase in total walking time, the odds of achieving the ODQ SCB change threshold increased by 18% (Exp(β) 1.18, 95%CI 1.01–1.37) (Table 6). In addition, a pre-operative pain duration of less than 12 months and lower pre-operative function (higher ODQ score) predicted achievement of the SCB threshold on the ODQ (Table 6).

Total walking time was not predictive of achieving the SCB change threshold on the SF-36 (PCS) or leg pain scores at six months. An age of less than 65 years old, and pre-operative pain of less than 12 months predicted achievement of the SCB threshold (Table 6). There were no significant predictors for achieving the SCB change threshold for back or leg pain.

Table 4 Summary of Included and Excluded Data

	Excluded (N)	Included (N)
Invited to participate:		262
Declined	17	
Excluded		
Unable to provide informed consent	4	
Co-existing condition limiting walking	6	
Withdrew consent	2	
Completed pre-operative OM's and activity monitoring:		233[a]
Lost/faulty monitor	27	
Incomplete monitoring period	16	
Incomplete outcome measures	19	
Data sets available for multivariable analysis:		171
Included in multivariable analysis[b]:		
ODQ	14	157
SF-36 (PCS)	17	154
Back pain	n/a	n/a
Leg pain	18	196[c]

OM's Outcome measures, *ODQ* Oswestry Disability Questionnaire, *SF-36 (PCS)* Short Form 36 Physical Component Summary
[a]Total number included in sensitivity analysis using multiple imputation to estimate missing data; [b]Remaining exclusions from individual regression analyses were due to incomplete individual outcome measures or missing independent variable data; [c]Walking time was not significantly correlated with change in leg pain, the 43 participants with missing activity monitor data included in the multivariable analysis

Sensitivity analysis

Total walking time remained a significant predictor of functional recovery (change in ODQ score from pre-operative to six months post-operative) using a linear regression model (B = 1.54; 95%CI 0.60–2.48) (Additional file 1: Table S4 in Appendix). When using multiple imputation models to estimate missing data, total walking time was not a significant predictor of functional recovery or change in pain scores, using either logistic or linear regression analysis (Additional file 1: Table S5, S6 in Appendix).

Discussion

This study found that greater walking time in the first post-operative week was associated with substantial improvement in self-reported function (ODQ), six months after lumbar surgery. In addition to walking time, experiencing pain for 12 months or less prior to surgery, poor pre-operative physical function and being younger than 65 years were associated with substantial improvement in function on the ODQ and/or the SF-36 (PCS) at six months.

The association between greater post-operative walking time and improved physical function has several implications. Greater walking time early after surgery may be an early indication of a successful surgical intervention, resulting in greater longer-term functional recovery. These patients with a greater walking time may therefore need less formal post-operative rehabilitation. Conversely, patients with a lower post-operative walking time may require more intensive rehabilitation to achieve substantial improvement in physical function. However, while this research suggests that the current focus of physiotherapy intervention on walking may be justified [10–12], further research is required to determine whether providing intervention targeted towards increasing walking time early after surgery then leads to improved longer-term outcome.

There was little overlap in the variables that predicted substantial improvement between the two measures of physical function, which likely reflects the differences in

Table 5 Outcome measurement: preoperative and six months post-operative; achievement of change thresholds

Outcome	Outcome measure	Baseline mean (SD)	Six months mean (SD)	Difference in mean (95%CI)	*t*-statistic, *p*-value	MCID N (%)	SCB N (%)
Physical function	ODQ	44.14 (16.35)	22.37 (17.43)	21.77 (18.44–25.10)	$t = 15.97$, $p = < 0.01$	142 (71%)	102 (51%)
	SF-36 (PCS)	32.89 (7.07)	43.74 (10.03)	−10.85 (−9.12 - -12.60)	$t = 15.10$, $p = < 0.01$	139 (72%)	127 (66%)
Back Pain	NRPS	5.75 (2.78)	2.88 (2.61)	2.87 (2.33–3.40)	$t = 12.52$, $p = < 0.01$	127 (64%)	107 (54%)
Leg Pain	NRPS	5.90 (3.02)	2.25 (2.66)	3.57 (3.08–4.22)	$t = 14.14$, $p = < 0.01$	134 (68%)	114 (58%)

MCID Minimal Clinically Important Difference, *SCB* Substantial Clinical Benefit, *ODQ* Oswestry Disability Questionnaire, *SF-36 (PCS)* Short Form 36 Physical Component Summary, *NRPS* Numerical Pain Rating Score

construct between the two measurement tools. Greater walking time was predictive of functional recovery on the ODQ but not the SF-36 (PCS). As the ODQ is designed to directly measure the impact back pain related disability has on physical function [36] it is unsurprising that walking, a form of physical activity, was associated with greater change on the ODQ. In contrast, the physical component summary of the SF-36 is designed to assess physical function in relation to Health Related QOL (HRQOL), and takes into account physical role, bodily pain, general health and mental health, in addition to physical function [37]. This broader definition may explain why alterations to physical activity in isolation did not influence change on the SF-36 (PCS). These results suggest that the ODQ and the SF-36 (PCS) measure distinctly different constructs in this population, a finding consistent with previous research [38].

No patient variables were found to be predictive of substantial improvement in back or leg pain in the multivariable logistic regression model, however on sensitivity analysis restricted pre-operative mobility was predictive of improvement in back-pain scores, and female sex was predictive of improvement in leg pain scores. Sensitivity analysis was conducted using linear regression analysis, where the change in pain from pre to post-operative was assessed as a continuous score rather than dichotomized based on the substantial clinical benefit threshold. This discrepancy may indicate that while restricted pre-operative mobility and female sex are significantly associated with improvement in pain scores, the change in pain over time may not represent a clinically meaningful improvement.

The overall change in outcome after lumbar surgery reported in this study are comparable with previously published results [7, 39]. While the majority of patients achieved the threshold required to demonstrate substantial improvement in function and pain, around a third did not achieve a minimal clinically important change in outcome. As the substantial clinical benefit threshold was used to dichotomize the data for the logistic regression analysis, we can be confident that these results represent clinically meaningful change, which is of particular importance as the benefit of surgical intervention for lumbar spine pathology remains inconclusive [4–6]. These findings do however emphasize the need for further investigation into interventions designed to optimize longer term recovery of physical function.

Limitations

There are several limitations to this study that need to be considered when interpreting these results. Up to 34% of participants who completed the monitoring period were not included in the multivariable analysis, and exclusion of these participants may limit how well the final sample reflects the broader population. However, as there was no statistically significant difference in the pre-operative or demographic variables between the participants that were included in the final analysis and those that were not, we are confident that these findings are representative of a larger sample.

Table 6 Multivariable logistic regression analysis

Outcome measure	Variable	β	Exp (β)	(95% CI)
ODQ	Total post-operative walking time (hours)	0.16	1.18	(1.02–1.37)
	Pre-operative pain duration < 12 months	1.00	2.71	(1.28–5.74)
	Pre-operative function (ODQ categories[a])	1.39	4.02	(2.33–6.93)
SF-36 (PCS)	Age < 65	0.86	2.36	(1.14–4.85)
	Pre-operative pain duration < 12 months	1.26	3.52	(1.69–7.33)

Interpretation of results: Exp (β) is equivalent to the odds ratio (OR). The predictor variables may be applied to determine the odds of achieving the SCB threshold for the given outcome measure. For example, for each additional hour of walking the odds of achieving ODQ SCB increases by 18%; for a participant less than 65 years old, the odds of achieving the SF-36 (PCS) SCB is 2.36 greater than those 65 years or over

ODQ, Oswestry Disability Questionnaire; SF-36 (PCS), Short Form 36 Physical Component Summary; [a]ODQ categories: 1: 0–20, 2: 21–40, 3: 41–59, 4: 60–79, 5: 80–100 (reference value: ODQ score 0–20)

As this research was conducted at a single site, the external validity of this study may be limited. However, patients of 11 different surgeons were included in this study all with differing post-operative protocols, and the presenting characteristics of the patients were consistent with those reported by other spinal surgery studies [7]. Further research across additional settings and patient populations would increase the confidence that these findings are more broadly generalizable.

The aim of this study was to investigate the direct association between patient variables and recovery of physical function after lumbar surgery with routine peri-operative care. Patient care was not standardised or modified in any way from usual care in the hospital setting, and the study was not designed to investigate a specific therapy or exercise intervention. Regression analysis was therefore most suited to examine the direct associations between patient variables and recovery after surgery. It is possible that parameters of the individual peri-operative rehabilitation program, such as the type, intensity, frequency or duration of exercise may have directly influenced outcome at six months, or interacted with the patient variables being examined in this study to indirectly impact outcome. However, our study was not designed to explore more complex predictive models such as an omnibus test of mediation, and as such the parameters of peri-operative rehabilitation were not recorded. Now that a direct association between walking and post-operative outcomes has been established in our study, future research needs to examine the mechanisms driving this relationship by means of more complex models such as mediation analysis.

Conclusion

This study found that people who spend more time walking in the week after lumbar surgery were more likely to experience substantial improvement in physical function at six months, as measured on the ODQ. Further research is required to ascertain whether intervention designed to increase walking early after lumbar surgery leads to improved recovery of function.

Additional file

Additional file 1: Table S1. Characteristics of Included and Excluded Participants (continuous data, independent *t*-tests). **Table S2.** Characteristics of Included and Excluded Participants (dichotomous/categorical data, Chi Squared). **Table S3.** Univariate analysis – correlation between predictor variables and achieving the SCB change threshold. **Table S4.** Sensitivity analysis. Linear regression analysis – change in outcome from pre-operative to six months post-operative. **Table S5.** Sensitivity analysis. Logistic regression analysis (multiple imputation) – achievement of SCB threshold. **Table S6.** Sensitivity analysis. Linear regression analysis (multiple imputation) – change in outcome from pre-operative to six months post-operative. (DOCX 40 kb)

Abbreviations

BMI: Body Mass Index; EVP: Events per Predictor Variable; GAD-7: Generalized Anxiety Disorder 7-item Scale; HRQOL: Health Related Quality of Life; IPAQ-SF: International Physical Activity Questionnaire Short Form; MCID: Minimum Clinically Important Difference; NPRS: Numerical Pain Rating Scale; ODQ: Oswestry Disability Questionnaire; OM: Outcome Measure; OR: Odds Ratio; PHQ-9: Patient Health Questionnaire Depression Scale; SCB: Substantial Clinical Benefit; SF-36 (PCS): Short Form 36 Physical Component Summary; SVPHM: St Vincent's Private Hospital Melbourne

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Authors' contributions

SJG, MD and JAM made a substantial contribution to the study design. All authors (SJG, AH, MD and JAM) made a substantial contribution to the data analysis and interpretation. SJG AH and JM made a substantial contribution towards writing up the manuscript. All authors have read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Ethics approval was obtained from the St Vincent's Hospital Melbourne Human Research Ethics Committee (Reference: LRR 098/15). Written, informed consent was obtained from all individual participants included in the study.

This study was retrospectively registered with the Australian New Zealand Clinical Trials Registry (ANZCTR) on the 7th June 2016, registration number 12616000747426.

Consent for publication

Not applicable.

Competing interests

The Authors have no conflicts of interest to declare.

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Publisher's Note

Chapter 8: Discussion

8.1. Summary of findings

This thesis is composed of five individual studies, addressing the following aims:

1. To systematically review the existing evidence investigating the effect of physiotherapy interventions before and immediately after lumbar spinal surgery.
2. To describe current peri-operative physiotherapy management of adults undergoing lumbar spinal surgery in Australia.
3. To evaluate the validity of the ActivPAL3©, Fitbit Flex© and Jawbone Up Move© activity monitors when measuring step count in patients early after lumbar fusion surgery.
4. To describe the physical activity patterns of patients in the first week after lumbar spinal surgery, and to investigate whether participant characteristics, surgical factors, or post-operative pain and function may explain variation in activity over this time period.
5. To establish the relationship between time spent walking in the first week after lumbar surgery and recovery of pain and physical function at six months.

The initial two aims of this thesis were addressed in the studies described in Chapters 2 and 3. A systematic review of the literature was conducted to evaluate the current evidence for physiotherapy before and immediately after lumbar surgery (Aim 1; Chapter 2). Due to the low number of included studies and considerable heterogeneity of the study designs and of the interventions assessed, this review concluded that there was limited evidence to guide physiotherapy practice in this field. Following on from the systematic review, an Australian wide survey of current practice was conducted (Aim 2; Chapter 3). This survey determined that almost all patients undergoing lumbar surgery in Australian hospitals are seen by a physiotherapist during their hospital inpatient admission, with all physiotherapists providing education and/or training in mobility tasks and walking.

Together, the findings from the systematic review and the survey of current practice indicate that although physiotherapy intervention is commonly provided to patients during an inpatient admission for lumbar spine surgery, there is very little research to guide evidence-based physiotherapy practice in this setting. Further research is therefore required to determine which physiotherapy interventions, if any, contribute to improved patient outcomes.

The survey of current practice identified a range of physiotherapy interventions provided in the early post-operative period, that varied considerably across the participating hospitals. Despite this variability, increasing walking from early after surgery was a consistent goal of treatment. While there is a growing body of evidence to link low activity levels during a hospital admission with poorer patient outcomes (Kalisch et al., 2013), it is not known whether more walking is associated with improved outcomes after lumbar spinal surgery.

To further investigate walking after lumbar surgery, a valid means of quantifying walking in this patient group was required (Aim 3; Chapter 4). The use of accelerometers to measure physical activity parameters, including step count and walking time, is now common practice. However, there was limited knowledge regarding the validity of accelerometers when measuring step count in people with an uneven or irregular gait pattern, as is typical early after lumbar surgery. A study was therefore conducted to determine the validity of the ActivPAL3©, Fitbit Flex© and Jawbone Up Move© activity monitors when measuring step count in patients early after lumbar fusion surgery. This study determined that the ActivPAL3© provided a valid measure of step count. Neither the Fitbit© nor the Jawbone© measured step count with sufficient accuracy to be used with this patient population. The ActivPAL3© was therefore used to measure step count and walking time in the subsequent study.

Observing the activity patterns of patients over the first six days after lumbar surgery (Aim 4, Chapter 6) demonstrated that although walking time increases over the first week after surgery, patients spent an average of only three percent of their time walking. While this patient group was notably more active than previously reported hospital inpatient populations (Agostini et al., 2014; Baldwin et al., 2017; Browning et al., 2007; Davenport et al., 2015) the majority of patient time was still spent in sedentary positions. When examining the association between step count and factors that potentially limit walking (Aim 4; Chapter 6), lower step count was associated with older age, a longer duration of and more severe pre-operative back pain, and undergoing a fusion procedure (compared to a decompression or discectomy). A lower step count was also associated with more severe post-operative pain, the presence of post-operative complications such as dizziness and nausea, and requiring supervision while walking. On examination of the relationship between walking and patient discharge outcomes, a lower step count was associated with a longer hospital stay and an increased likelihood of discharge to a rehabilitation facility.

The final aim of this thesis was to establish whether the time spent walking in the first week after lumbar surgery predicted substantial recovery of longer-term physical function (Aim 5; Chapter 7). This study found that greater walking time in the immediate post-operative period was predictive of substantial improvement in physical function six months after surgery. In addition to walking time, experiencing pre-operative pain for less than 12 months, having low pre-operative physical function and being younger than 65 years old were predictive of substantial improvement in function at six months.

8.2. Implications of findings

8.2.1. Increased walking time early after lumbar surgery is associated with improved functional recovery six months after surgery.

The final study in this thesis (Chapter 7) identified an association between greater walking time early after lumbar surgery, and an increased likelihood of achieving substantial improvement in physical function at six months (Gilmore et al., 2019b). These results indicate that for every additional hour of walking in the first six post-operative days, the odds of achieving substantial improvement in physical function (defined as an improvement on the ODQ of 18.8 points or greater) increased by 18%.

While further research is required to establish whether physiotherapy intervention designed to increase post-operative walking leads to an improvement in longer term physical function, these results may be used to provide preliminary support for current physiotherapy practice early after lumbar surgery, where walking is a predominant focus of intervention (Gilmore et al., 2016).

The positive association between increased walking and improved post-operative functional recovery raises several possibilities that may be used to formulate future research questions. It may be possible to identify patients who require ongoing rehabilitation services based on the amount of walking they do early after surgery. Patients who walk more are likely to have a good functional outcome, and may therefore require less formal rehabilitation. Conversely, patients who spend very little time walking may be at risk of a poor outcome, and may therefore benefit from an intensive rehabilitation program designed to improve longer term physical function.

It is also possible that post-operative walking time may be used in combination with the other patient variables that were identified as being predictive of patient outcome, to identify patients who require a more intensive post-operative rehabilitation program. A pre-operative pain duration of less than 12 months and being 65 years or younger were also predictive of substantial improvement in physical function six months after surgery (Gilmore et al., 2019b). Based on these results, patients 65 years or older who had pre-operative pain for longer than 12 months, who participate in minimal walking early after surgery are at a higher risk of poor post-operative outcome, and may potentially benefit from early post-operative rehabilitation. Further research is required to explore these hypotheses.

8.2.2. The ActivPAL3© accelerometer provides a valid measure of step count early after lumbar surgery.

The ActivPAL3© accelerometer was a valid measure of step count for patients within the first three days after lumbar surgery (Gilmore et al., 2018). A strong correlation was observed between the steps detected by the ActivPAL3© and direct observation, with the ActivPAL3© detecting 88% of all steps taken. In addition, there was no association between the accuracy of step count detection and gait speed, indicating that the ActivPAL3© provided a valid measure of step count regardless of the speed at which participants were walking. These findings suggest that the ActivPAL3© can confidently be used to measure step count in the acute hospital setting for patients early after lumbar surgery.

In addition, while several studies have investigated the validity of activity monitors in other patient populations (Fulk et al., 2014; Ng et al., 2012; Treacy et al., 2017), few have looked specifically at groups with a high likelihood of having a slow or asymmetrical gait, or those who use a gait aid. Based on the results of the study presented in Chapter 4 (Gilmore et al., 2018), it is probable that the ActivPAL3© will provide a valid measure of step count in patients in similar settings with similar gait characteristics. The ActivPAL3© should therefore be considered by researchers and clinicians when measuring step count in similar patient populations.

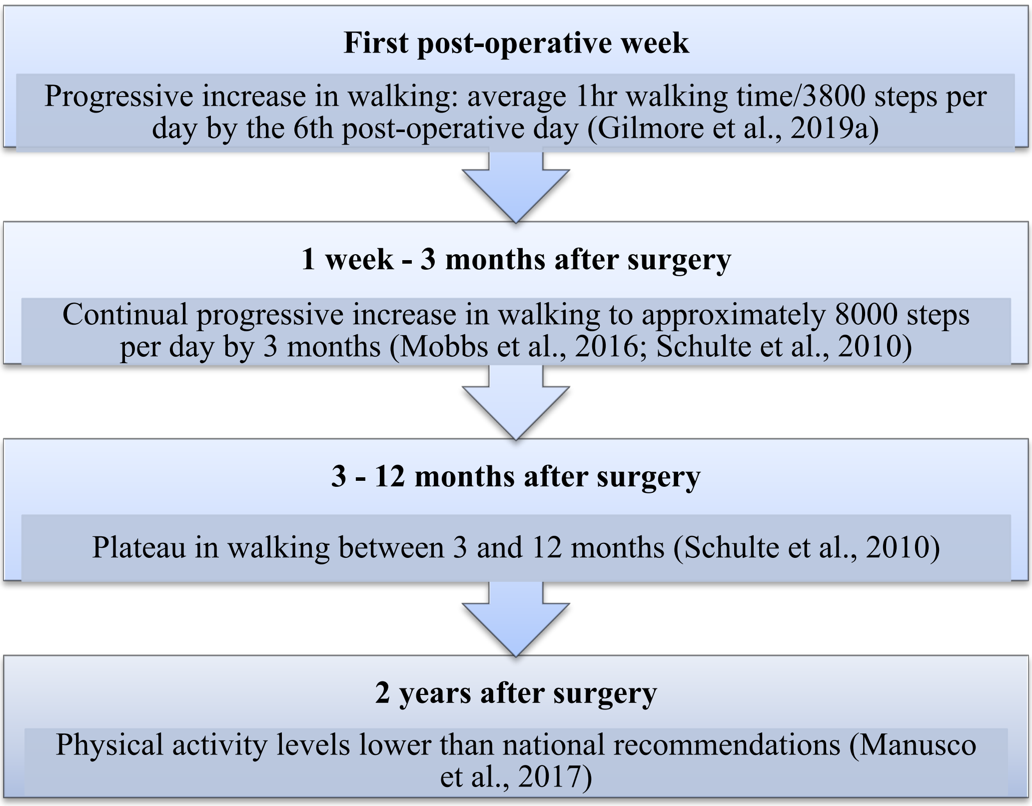
8.2.3. The commercially available accelerometers did not provide a valid measure of step count early after lumbar surgery.

The two commercially available accelerometers (Fitbit Flex© and Jawbone UP Move©) had very low accuracy rates for detecting step count early after lumbar surgery when worn on the wrist, particularly in patients with a slower walking speed (Gilmore et al., 2018). When arm swing was eliminated due to the use of a gait aid, the accuracy was further reduced. To determine whether placing the accelerometers in a position that did not rely on arm swing and would therefore be unaffected by the use of a gait aid, they were also tested on the thigh in the same position as the ActivPAL3©. While the Fitbit Flex© was significantly more accurate when tested on the thigh than the wrist, it was not accurate enough to be considered a valid measure of step count early after lumbar surgery. The Fitbit Flex© and Jawbone UP Move© were therefore not appropriate for use in the post lumbar surgery population, even in a modified position.

These findings demonstrate that commercially available accelerometers do not consistently provide an accurate measure of step count in the presence of an abnormal gait pattern, and support the hypothesis that monitor accuracy may be reduced in patients who have a slow gait or absent arm swing. This emphasises the need to ensure accelerometers used in the research setting have been validated in the specific population of interest prior to use.

8.2.4. Patients spend very little time walking in the week after lumbar surgery.
The study presented in Chapter 6 (Gilmore et al., 2019a) is the first known study to describe physical activity patterns of patients early after lumbar surgery. These findings, in combination with similar studies describing activity patterns at other post-operative time points, may be used to guide expectations for normal recovery of physical activity after lumbar surgery (Figure 8.1).

Figure 8.1. Flow chart illustrating known normal increases in physical activity after lumbar surgery.



While the findings from this study and the research referred to in Figure 8.1 increase our understanding about typical activity patterns following lumbar spine surgery, it is not yet known how much activity patients should aim to do from early after surgery to optimise post-operative outcome. Further research is required to develop evidence based physical activity guidelines specific to the lumbar surgery population, that may be used to guide post-operative rehabilitation programs.

In the absence of physical activity recommendations specific to this patient population, the findings may be compared to general physical activity recommendations. To maintain general health, the national physical activity guidelines recommend adults exercise at a moderate intensity (i.e. brisk walking) for thirty minutes, five days of the week, in bouts of at least ten minutes at a time (Australian Government Department of Health, 2012). While the average total daily walking time of participants in this study exceeded thirty minutes by the second post-operative day, the majority of walking bouts were less than five minutes long with a mean step count of less than one hundred steps. Based on these figures, it is unlikely that the majority of participants achieved a moderate intensity of activity for a minimum of ten minutes in a single walking bout or that this walking could be considered "brisk", and it is therefore unlikely that the recommended daily activity levels were met. However, it is probable that the targets outlined in the national guidelines do not represent a realistic or appropriate activity goal in the acute post-operative phase. While the recommended activity levels may be used to guide longer term rehabilitation goals, further research is required to determine realistic timeframes in which patients can progress walking and other physical activities following surgery in order to achieve these targets.

8.2.5. Reduced step count early after lumbar surgery is associated with a longer hospital admission, and an increased likelihood of discharge to a rehabilitation facility.

This research found that patients in the bottom quartile for total step count over the first six days after surgery had a median length of stay three times greater than those in the top quartile. In addition, those in the bottom 25% were almost six times more likely to be discharged to a rehabilitation facility than those in the top 25% (Chapter 6).

These findings indicate that a lower step count is associated with a prolonged hospital admission. Patients with a lower step count may therefore place a greater demand on health care resources compared to those with a higher step count. Given the financial implications of a longer hospital admission, whether it be in the acute or rehabilitation setting, these findings emphasise the need to better understand the impact that early physical activity has on discharge outcomes.

These findings generate two hypotheses that require further investigation. First, it may be possible to provide intervention targeted specifically towards increasing walking time from early after surgery to reduce the length of stay and/or the need for inpatient rehabilitation. Second, it may be possible to use low walking time/step count to identify patients who may be more likely to require rehabilitation prior to discharge home. Earlier identification of these patients may in turn facilitate earlier referral and transfer to rehabilitation, potentially reducing the length of stay in the acute hospital setting.

8.2.6. Reduced step count early after lumbar surgery is associated with an increased incidence of post-operative pain, nausea and vomiting.

Greater post-operative pain, and experiencing post-operative nausea and vomiting was associated with a lower step count early after surgery (Gilmore et al., 2019a). It is probable that these factors are closely interrelated with post-operative pain and nausea, reducing the ability and motivation to walk, while walking may increase the severity of poorly managed pain and nausea. Further research is required to determine whether better management of post-operative symptoms that potentially limit activity has an impact on either walking time early after surgery, or longer-term patient outcome.

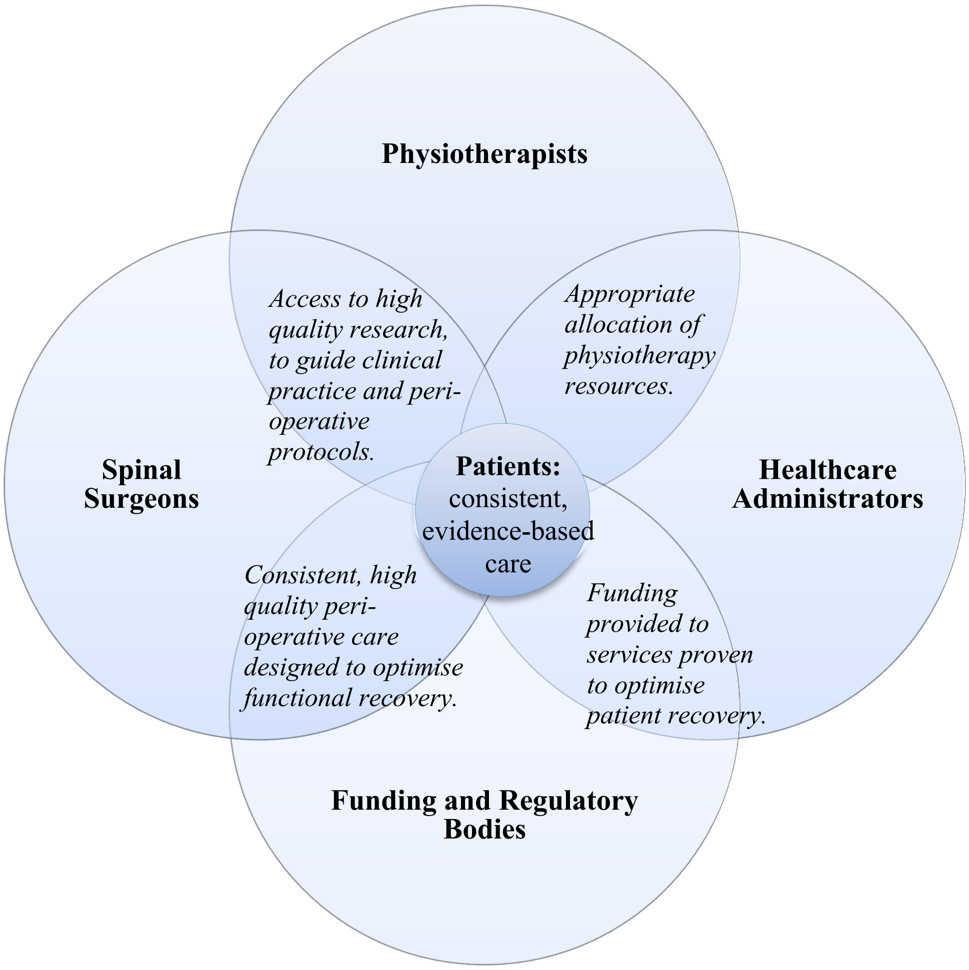
8.2.7. An increase in walking time was not associated with an increase in post-operative complications.

One potential cause for concern is that increased post-operative walking time may be associated with an increased rate of post-operative complications. This research found no association between greater walking time and complications requiring further medical or surgical intervention, suggesting that walking is a safe form of activity that can commence early after surgery (Gilmore et al., 2019b).

8.2.8. There is little evidence to guide physiotherapy management of patients undergoing lumbar surgery, leading to inconsistent physiotherapy practice.

The findings from the first two studies of this thesis indicate that although physiotherapy intervention is a routine component of care early after lumbar surgery (Gilmore et al., 2016) it is currently not known which, if any, interventions contribute to an improvement in patient outcome (Gilmore et al., 2015). As illustrated in Figure 8.2, a robust evidence base is crucial for the provision of consistent and coordinated patient care, to guide the decision making processes of physiotherapists, spinal surgeons, administrators of healthcare organisations, and funding and regulatory bodies. A lack of evidence to guide practice may therefore have a broad impact on peri-operative patient management.

Figure 8.2. Understanding the need for a robust evidence base to guide physiotherapy practice before and immediately after lumbar surgery



The current lack of evidence likely contributes to the inconsistencies in patient management before and early after surgery. This thesis found a high variability in physiotherapy practice across Australian hospitals (Gilmore et al., 2016), particularly regarding post-operative movement and activity restrictions, and exercise prescription. Similar variability has been shown amongst physiotherapists in the UK (Rushton et al., 2014; Williamson et al., 2007), and spinal surgeons in Australia and the UK (Daly et al., 2018; McGregor et al., 2006). Collectively, this overall variability in practice suggests that current post-operative protocols are predominantly based on individual or organisational best practice beliefs rather than evidence-based protocols, an unsurprising finding given the lack of research to guide the development of such protocols.

Despite this variability in practice, it appears that patient management models in Australia (Gilmore et al., 2016) and the UK (Rushton et al., 2014; Williamson et al., 2007) are based on the assumption that routine post-operative physiotherapy intervention is beneficial, as the majority of patients receive physiotherapy intervention during their inpatient admission. It is important to note that the uncertainty in regard to the effectiveness of physiotherapy intervention is due to a lack of evidence, as opposed to evidence to suggest physiotherapy intervention is ineffective. However, without clear evidence that physiotherapy intervention either prior to or early after lumbar surgery improves patient outcome, it is likely to become increasingly difficult to secure funding for physiotherapy services provided to this patient group. This is particularly relevant given the rapid growth in the number of lumbar surgeries performed (Harris and Dao, 2009; Rajaee et al., 2012), the uncertainty regarding the true benefit of lumbar surgery (Bydon et al., 2014; Jacobs et al., 2011; Kovacs et al., 2011; Machado and Ferreira, 2017; May and Comer, 2013; Weinstein et al., 2010; Zania et al., 2016), and the subsequent scrutiny of practice by regulatory and funding bodies (Australian Commission on Safety and Quality in Health Care, 2017). Further research is required to determine whether physiotherapy intervention provides a cost-effective means of improving patient outcome after lumbar surgery.

8.3. Strengths and limitations

There are a number of strengths and limitations to consider when interpreting this thesis. One strength is the sequential manner in which this research was conducted, with the initial two studies informing the research questions for the following studies. This method was used to ensure the thesis addressed an identified gap in the current research and focused on a topic that had the potential to be readily translated into clinical practice. Findings from the survey of current practice (Gilmore et al., 2016) indicated that considerable resources are invested into this patient group, and research to determine the importance of physiotherapy intervention in this setting is therefore necessary to ensure appropriate allocation of healthcare resources. In addition, while current clinical practice was variable, intervention with a focus on resuming walking was common across all participating hospitals (Gilmore et al., 2016).

We were therefore confident that focusing further research on walking and interventions that may increase walking, was reflective of current clinical practice.

The two final studies in this thesis used accelerometery to measure step count and walking time early after lumbar surgery. While accelerometry is a widely used tool to objectively measure physical activity, at the time of this study there was little information available regarding the validity of accelerometers in patient populations, particularly those with slow or irregular gait patterns. The third study of this thesis (Chapter 4) was therefore designed to assess the validity of accelerometers when measuring step count in patients early after lumbar surgery. These findings ensured that the accelerometer used in the subsequent study provided a valid and accurate measure of step count in the lumbar surgery population.

To ensure findings from this research were clinically meaningful, the substantial clinical benefit (SCB) threshold was used to determine change in physical function and pain over time. The minimal clinically important difference (MCID) has been well established within the low back pain and lumbar surgery literature, and is used to determine whether change in outcome reflects minimal important change for the patient (Chapman et al., 2011; Glassman et al., 2008). The threshold required to demonstrate substantial clinical benefit, however, represents substantial improvement in outcome as perceived by the patient (Glassman et al., 2008). By demonstrating that increased walking time is associated with substantial (as opposed to minimal) improvement in physical function, we can be confident that these results represent change that is meaningful to this patient population.

There are several limitations that need to be considered when interpreting the findings of this thesis. The final two studies (presented in Chapters 6 and 7) were conducted at a single site which may limit the generalisability of the results, particularly given that peri-operative care is known to be variable between hospitals (Gilmore et al., 2016; Rushton et al., 2014; Williamson et al., 2007). However, the overall post-operative outcomes were consistent with previously reported spinal surgery studies (Weinstein et al., 2010) indicating that that this study population has similarities with the broader spinal surgery population. In addition, this research included the patients of eleven neurosurgeons, all with differing postoperative protocols. This inherent internal variability may increase the generalisability of the results, however it is not known whether this is representative of the wider between-hospital variability. Further research is required to determine whether these finding are generalisable across other patient populations and settings.

In the final study, which examined the association between walking time and longer-term outcome (Chapter 7), approximately one third of participants were excluded from the multivariable analysis due to incomplete data. Just over half of the exclusions were due to incomplete outcome measures or an incomplete monitoring period. It is possible that participants who did not complete the outcome measures or monitoring may also have completed less walking than participants with a complete data set. This may limit how well the final results reflect the overall population, however as there were no significant differences between the included and excluded participants at baseline systematic bias is unlikely, and it is probable that the final results were representative of the initial sample.

In the studies presented in Chapters 6 and 7, complications were primarily self-reported by participants rather than reported from medical records. It is therefore possible that post-operative complications were underreported. It is also possible that participants who did not complete the monitoring period or six-month follow-up may have experienced a higher complication rate, again resulting in underreporting. As an increased complication rate is a possible consequence of increasing physical activity early after lumbar surgery, all future research investigating physical activity after lumbar surgery should routinely and rigorously monitor post-operative complications.

8.4. Implications for future research

Due to the scarcity of evidence to guide physiotherapy practice early after lumbar surgery, it was intended that this body of work would provide a foundation of knowledge to inform future research in this field. As anticipated, this thesis has identified a number of opportunities for ongoing research that may have the potential to directly influence physiotherapy practice and patient outcome.

8.4.1. What are the safe and realistic timeframes over which patients may increase their physical activity levels after lumbar surgery?

There is currently no knowledge about how much walking is safe after lumbar surgery, or how quickly patients can resume their volume or intensity of walking. There is a need for evidence-based guidelines around returning to walking and physical activity after lumbar surgery to guide the design of post-operative rehabilitation programs. Further study is required to address the following question: What are the safe and realistic timeframes over which patients may increase their physical activity levels from immediately after lumbar surgery?

8.4.2. Does increasing the amount of walking patients do early after lumbar surgery improve post-operative recovery?

Greater walking time was associated with improved recovery of physical function six months after lumbar surgery. It is possible that increasing walking time early after surgery may improve longer-term recovery of function, however there is no research as yet to explore this hypothesis. To investigate this further, a randomised controlled trial is required to address the question: Does physiotherapy intervention designed to increase walking time early after lumbar surgery result in greater improvement in physical function?

8.4.3. Does intensive rehabilitation for patients with low activity levels early after lumbar surgery improve longer-term functional recovery?

These findings indicate that a low step count early after lumbar surgery may be used to identify patients at risk of a poor post-operative outcome. These patients may subsequently benefit from an intensive rehabilitation program commencing early after surgery, aiming to improve early walking and longer-term function. To investigate this possibility, a randomised controlled trial is required to address the question: Does intensive rehabilitation for patients with low activity levels early after lumbar surgery improve longer-term functional recovery?

8.4.4. Does increasing the walking time of lumbar surgery patients in the hospital inpatient setting improve length of stay or alter discharge destination?

In this thesis, lower step count was associated with a longer hospital admission, and an increased likelihood of transfer to a rehabilitation facility. It may therefore be possible to improve discharge outcomes by increasing step count during the inpatient admission. However, as previously discussed it is likely that step count is influenced by post-operative complications such as pain and nausea, which together contribute to poor discharge outcomes. To determine the true nature of this relationship the following questions need to be addressed:

- Does increasing the walking time of lumbar surgery patients in the hospital inpatient setting improve length of stay or alter discharge destination?
- Does improved multidisciplinary management of early complications after lumbar surgery, such as pain and nausea, result in increased walking time in the immediate post-operative period?
- Does improved multidisciplinary management of early complications after lumbar surgery, such as pain and nausea, improve length of stay or discharge destination?

8.4.5. Are there other physiotherapy interventions that improve recovery after surgery?

While resuming walking after lumbar surgery was found to be a common focus of early physiotherapy treatment across Australia, a number of other interventions were reported including exercise prescription, provision of advice and education, and functional task training (Gilmore et al., 2016). It was also evident that peri-operative care is multifactorial and multidisciplinary, involving a number of discrete interventions. Further research is required to explore the effectiveness of both physiotherapy specific interventions and multidisciplinary, multi-factorial rehabilitation programs, that are reflective of routine peri-operative care.

8.4.6. What is the optimal timing for physiotherapy intervention before and/or after lumbar surgery?

The nationwide survey conducted as part of this thesis identified several routine points of contact with a physiotherapist: pre-operatively, during the post-operative hospital admission, and in the outpatient setting. It is currently not known whether physiotherapy intervention at any of these time points improves post-operative outcomes (with the exception of outpatient physiotherapy at 4-6 weeks after surgery (Oosterhuis et al., 2014)). Further research is required to determine the benefit of providing intervention at these three identified points of contact.

8.4.7. How do we determine which patients will benefit from surgical intervention over conservative management?

More broadly, the findings from this thesis reinforce the need for high quality evidence to determine which patients, if any, benefit from surgical intervention over conservative management. There is also a need to identify reliable patient variables that predict either poor or very good outcome to guide patient selection for surgery. Improvement of the patient selection process will then aid the development of pre and post-operative rehabilitation programs designed to optimise pain management, functional recovery, and quality of life after surgery.

8.5. Conclusion

Although increasing walking after lumbar spinal surgery is a common goal of early post-operative physiotherapy intervention, this research shows that patients do very little walking in the first week after surgery. Reduced walking time was found to be associated with poorer patient outcome both in the short term (length of stay and discharge destination) and long term (recovery of physical function). Further research is therefore required to determine whether physiotherapy intervention designed to increase walking time from early after surgery results in subsequent improvements in short and long-term patient outcomes.

Appendix I: Statements of Ethics Approval

1. La Trobe University Faculty Human Ethics Committee: Physiotherapy management of patients undergoing lumbar spinal surgery: a survey of Australian physiotherapists (Chapter 3).

2. St Vincent's Hospital Melbourne Human Research Committee: Does early post-operative physical activity predict recovery of function six months after lumbar spinal surgery? (Chapters 4, 5, 6 and 7).

3. St Vincent's Private Hospital Melbourne Human Research Committee: Does early post-operative physical activity predict recovery of function six months after lumbar spinal surgery? (Chapters 4, 5, 6 and 7).

4. La Trobe SHE College Human Research Sub-Committee: Does early post-operative physical activity predict recovery of function six months after lumbar spinal surgery? (Chapters 4, 5, 6 and 7).

LA TROBE UNIVERSITY

FACULTY OF HEALTH SCIENCES

MEMORANDUM

To: **Megan Davidson – Department of Physiotherapy**

Student: **Sarah Gilmore**

From: **Chair, La Trobe University Faculty Human Ethics Committee**

Reference **FHEC13/146**

Title: **Physiotherapy management of patients undergoing lumbar spinal surgery for degenerative conditions**

Date: **15 July, 2013**

Thank you for your recent correspondence in relation to the research project referred to above. The project has been assessed as complying with the *National Statement on Ethical Conduct in Human Research*. I am pleased to advise that your project has been granted ethics approval and you may commence the study now.

The project has been approved from the date of this letter until 30 June, 2014.

Please note that your application has been reviewed by a sub-committee of the University Human Ethics Committee (UHEC) to facilitate a decision before the next Committee meeting. This decision will require ratification by the UHEC and it reserves the right to alter conditions of approval or withdraw approval at that time. You will be notified if the approval status of your project changes. The UHEC is a fully constituted Ethics Committee in accordance with the National Statement under Section 5.1.29.

The following standard conditions apply to your project:

- **Limit of Approval.** Approval is limited strictly to the research proposal as submitted in your application while taking into account any additional conditions advised by the Faculty Human Ethics Committee (FHEC) .

- **Variation to Project.** Any subsequent variations or modifications you wish to make to your project must be formally notified to the FHEC for approval in advance of these modifications being introduced into the project. This can be done using the appropriate form: *Ethics - Application for Modification to Project* which is available on the Research Services website at *http://www.latrobe.edu.au/research-services/ethics/HEC_human.htm*. If the FHEC considers that the proposed changes are significant, you may be required to submit a new application form for approval of the revised project.

- **Adverse Events.** If any unforeseen or adverse events occur, including adverse effects on participants, during the course of the project which may affect the ethical acceptability of the project, the Chief Investigator must immediately notify the FHEC Secretary on telephone (03) 9479 3570 or at fhechealth@latrobe.edu.au.Any complaints about the project received by the researchers must also be referred immediately to the FHEC Secretary.

- **Withdrawal of Project.** If you decide to discontinue your research before its planned completion, you must advise the FHEC and clarify the circumstances.

- **Monitoring.** All projects are subject to monitoring at any time by the Faculty Human Ethics Committee.

- **Annual Progress Reports.** If your project continues for more than 12 months, you are required to submit an *Ethics - Progress/Final Report Form* annually, **on or just prior to 12 February**. The form is available on the Research Services website (see above address). Failure to submit a Progress Report will mean approval for this project will lapse.

- **Auditing**. An audit of the project may be conducted by members of the FHEC.

- **Final Report.** A Final Report (see above address) is required within six months of the completion of the project**.**

If you have any queries on the information above or require further clarification please contact me at fhechealth@latrobe.edu.au.

On behalf of the Faculty of Health Sciences Faculty Human Ethics Committee, best wishes with your research!

Owen M Evans, PhD
Chair
Faculty Human Ethics Committee
Faculty of Health Sciences

ST VINCENT'S HOSPITAL
MELBOURNE
A FACILITY OF ST VINCENT'S HEALTH AUSTRALIA

St Vincent's Hospital (Melbourne) Limited
ABN 22 052 110 755

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PO Box 2900 Fitzroy VIC 3065

Telephone 03 9288 2211
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20 October 2015

Dr Jodie McClelland
Department of Physiotherapy
St Vincent's Hospital (Melbourne)

Dear Dr McClelland

LRR 098/15 - 'Does early post-operative physical activity predict recovery of function six months after lumbar spinal surgery?'

Thank you for submitting your Low Risk Research activity for approval. The Low Risk Research Sub-committee of Human Research Ethics Committee (HREC)-A has approved the above mentioned project at the following sites:

1. St Vincent's Private Hospital (Melbourne)

This approval will be ratified by St Vincent's Hospital (Melbourne) HREC-A at the next meeting. Ethics approval is granted for a period of 4 years from the date of this letter.

The project complies with the principles of the *National Statement on the Ethical Conduct of Human Research* (NHMRC; 2007).

Approved documents
The following documents have been reviewed and approved:

Document	Version	Date
Low Risk Research Application	2	25 August 2015
Participant Information and Consent Form	3	16 October 2015
Research protocol	2	25 August 2015
SVPH Ethics Committee in principal approval letter	-	21 July 2015
Patient Health Questionnaire	-	-
Accelerometer record	-	-
Discharge letter	-	-
IPAQ	-	-
Oswestry Disability Index	-	-
Post-op (daily questionnaire)	-	-
Pre-op letter to participants	-	-

Six-month letter to participants	-	-
Six-month follow up	-	-
Your Health and wellbeing Survey	-	-

Terms of approval:

1. It is the responsibility of the Principal Researcher to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as specified in the application.
2. You should notify the Research Governance Unit immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
3. Amendments to the approved project: Changes to any aspect of the project require the submission of a Request for Amendment to the Low Risk Research Sub-committee and must not begin without written approval. Substantial variations may require a new application.
4. Future correspondence: Please quote the reference number and project title above in any further correspondence.
5. Annual Reports: An Annual Report is due on the anniversary of the date of approval
6. Final report: A Final Report must be provided at the conclusion of the project.
7. Monitoring: Projects may be subject to an audit or any other form of monitoring by the Research Governance Unit at any time.

We wish you well with your project.

Yours sincerely,

Ms Eleisha Taylor
Administrative Officer
Research Governance Unit
St Vincent's Hospital (Melbourne)

ST VINCENT'S PRIVATE HOSPITAL
MELBOURNE
A FACILITY OF ST VINCENT'S HEALTH AUSTRALIA

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Facsimile 03 9419 6582
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UNDER THE STEWARDSHIP OF MARY AIKENHEAD MINISTRIES

26 November, 2015

Sarah Gilmore
Physiotherapy Dept
St Vincents Private Hospital Melbourne
59 Victoria Parade
FITZROY VIC 3065

Dear Sarah

Re: R0239/15
Study: Does early post-operative physical predict recovery of function six months after lumbar spinal surgery

I am pleased to advise that at the last Research Meeting and the Operational Executive Committee of St Vincent's Private Hospital, the above proposal was approved. You may now proceed with the study.

Copies of any correspondence or reports sent to or received from St Vincent's Hospital Human Research Ethics Committee need to be forwarded to Ms Georgie Corke, Executive Assistant to the Medical Director, St Vincents Private Hospital.

Yours sincerely

Dr Bill Kelly
Medical Director

cc Ms Karen-leigh Edward – Director of Research, St Vincents Private Hospital

St Vincent's Private Hospital Fitzroy
59 Victoria Parade Fitzroy VIC 3065
Telephone 03 9411 7111
Facsimile 03 9419 6582

St Vincent's Private Hospital East Melbourne
159 Grey Street East Melbourne VIC 3002
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St Vincent's Private Hospital Kew
5 Studley Avenue Kew VIC 3101
Telephone 03 9851 8888
Facsimile 03 9853 1415

LA TROBE UNIVERSITY

COLLEGE OF SCIENCE, HEALTH & ENGINEERING

MEMORANDUM

To:	**Jodie McClelland**
Student:	**Sarah Gilmore**
From:	**Secretariat, SHE College Human Ethics Sub-Committee (SHE CHESC)**
Reference:	**SHE CHESC acceptance of St Vincent's Hospital Melbourne HREC approved project – LRR 098/15.**
Title:	**Does early post-operative physical activity predict recovery of function six months after lumbar spinal surgery?**
Date:	**18 November 2015**

Thank you for submitting the above protocol to the SHE College Human Ethics Sub-Committee (SHE CHESC). Your material was forwarded to the SHE CHESC Chair for consideration. Following evidence of a full review and subsequent final approval by the **The St Vincent's Hospital Melbourne HREC**, the SHE CHESC Chair agrees that the protocol complies with the National Health and Medical Research Council's *National Statement on Ethical Conduct in Human Research* and is in accordance with La Trobe University's *Human Research Ethics Guidelines*.

Endorsement is given for you to take part in this study in line with the conditions of final approval outlined by The St Vincent's Hospital Melbourne HREC.

Limit of Approval. La Trobe SHE CHESC endorsement is limited strictly to the research protocol as approved by The St Vincent's Hospital Melbourne HREC.

Variation to Project. As a consequence of the previous condition, any subsequent modifications approved by The St Vincent's Hospital Melbourne HREC for the project should be notified formally to the SHE CHESC

Annual Progress Reports. Copies of all progress reports submitted to The St Vincent's Hospital Melbourne HREC are to be forwarded to the SHE CHESC. Failure to submit a progress report will mean that endorsement for your involvement in this project will be rescinded. An audit related of your involvement in the study may be conducted by the SHE CHESC at any time.

Final Report. A copy of the final report is to be forwarded to the CHESC within one month of it being submitted by The St Vincent's Hospital Melbourne HREC.

If you have any queries related to the information above or require further clarifications, please contact chesc.she@latrobe.edu.au. Please quote reference number **LRR 098/15 – McClelland/Gilmore**.

On behalf of the College Human Ethics Sub-Committee, best wishes with your research!

Ms Kate Ferris
Human Ethics Officer
Secretariat – SHE College Human Ethics Sub-Committee
Ethics and Integrity / Research Office
La Trobe University Bundoora, Victoria 3086
E: chesc.she@latrobe.edu.au
P: (03) 9479 – 3370
http://www.latrobe.edu.au/researchers/ethics/human-ethics

Appendix II: Confirmation of Authorship

Publication 1

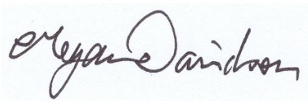
Statement from the co-authors confirming authorship contribution of the Ph.D. candidate:

"As co-authors of the paper "*Gilmore SJ, McClelland JA, Davidson M. (2014). Physiotheraputic interventions before and after surgery for degenerative lumbar conditions: a systematic review. Physiotherapy 101(2):111-8"* we confirm that Sarah Gilmore made the following contributions:

- Conception and design of study
- Data collection
- Analysis and interpretation of the data
- Writing the manuscript and response to the reviewers' comments

A/Prof. Jodie McClelland Date: 7/12/19

A/Prof. Megan Davidson Date: 7/12/19



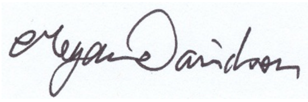
Publication 2

Statement from the co-authors confirming authorship contribution of the Ph.D. candidate:

"As co-authors of the paper *"Gilmore SJ, McClelland JA, Davidson M. (2016). Physiotherapy management of patients undergoing lumbar spinal surgery for degenerative conditions: a survey of Australian physiotherapists. New Zealand Journal of Physiotherapy 44(2):105-12"* we confirm that Sarah Gilmore made the following contributions:

- Conception and design of study
- Data collection
- Analysis and interpretation of the data
- Writing the manuscript and response to the reviewers' comments

A/Prof. Jodie McClelland  Date: 7/12/19

A/Prof. Megan Davidson  Date: 7/12/19

Publication 3

Statement from the co-authors confirming authorship contribution of the Ph.D. candidate:

"As co-authors of the paper "*Gilmore SJ, Davidson M, Hahne AH, McClelland JA. (2018). The validity of using activity monitors to detect step count after lumbar fusion surgery. Disability and Rehabilitation 16:1-6"* we confirm that Sarah Gilmore made the following contributions:

- Conception and design of study
- Data collection
- Analysis and interpretation of the data
- Writing the manuscript and response to the reviewers' comments

A/Prof. Jodie McClelland		Date: 7/12/19
Dr. Andrew Hahne		Date: 7/12/19
A/Prof. Megan Davidson		Date: 7/12/19

Publication 4

Statement from the co-authors confirming authorship contribution of the Ph.D. candidate:

"As co-authors of the paper *"Gilmore SJ, McClelland JA, Davidson M. (2016). Does walking after lumbar spinal surgery predict recovery of function at six months? Protocol for a prospective cohort study. BMC Musculoskeletal Disorders 17(1):472"* we confirm that Sarah Gilmore made the following contributions:

- Conception and design of study
- Data collection
- Analysis and interpretation of the data
- Writing the manuscript and response to the reviewers' comments

A/Prof. Jodie McClelland  Date: 7/12/19

A/Prof. Megan Davidson  Date: 7/12/19

Publication 5

Statement from the co-authors confirming authorship contribution of the Ph.D. candidate:

"As co-authors of the paper *"Gilmore SJ, Hahne AJ, Davidson M, McClelland JA. (2019). Physical activity patterns of patients immediately after lumbar surgery. Disability and Rehabilitation 15:1-7"* we confirm that Sarah Gilmore made the following contributions:

- Conception and design of study
- Data collection
- Analysis and interpretation of the data
- Writing the manuscript and response to the reviewers' comments

A/Prof. Jodie McClelland Date: 7/12/19

Dr. Andrew Hahne Date: 7/12/19

A/Prof. Megan Davidson Date: 7/12/19

Publication 6

Statement from the co-authors confirming authorship contribution of the Ph.D. candidate:

"As co-authors of the paper "*Gilmore SJ, Hahne AJ, Davidson M, McClelland JA. (2019). Predictors of substantial improvement in physical function six months after lumbar surgery: is early post-operative walking important? A prospective cohort study. BMC Musculoskeletal Disorders 20(1):418"* we confirm that Sarah Gilmore made the following contributions:

- Conception and design of study
- Data collection
- Analysis and interpretation of the data
- Writing the manuscript and response to the reviewers' comments

A/Prof. Jodie McClelland	Date: 7/12/19
Dr. Andrew Hahne	Date: 7/12/19
A/Prof. Megan Davidson	Date: 7/12/19

Appendix III: Physiotheraputic interventions before and after surgery for degenerative lumbar conditions: a systematic review (Chapter 2): Search Strategy

CENTRAL Search Strategy
#1 MeSH descriptor Back Pain explode all trees
#2 MeSH descriptor Spinal Diseases explode all trees
#3 Backache
#4 dorsalgia
#5 Lumbar next pain
#6 Back next pain
#7 Coccyx
#8 Coccydynia
#9 MeSH descriptor Spine explode all trees
#10 MeSH descriptor Sciatica explode all trees
#11 Sciatic*
#12 Spondylo*
#13 Lumbago
#14 Dis* near degenerat*
#15 Dis* near prolapse
#16 Dis* near herniation
#17 Discitis
#18 Slipped near dis*
#19 MeSH descriptor Arachnoiditis explode all trees
#20 Lumbar near vertebra*
#21 MeSH descriptor Cauda Equina explode all trees
#22 Spin* near stenosis
#23 Dis* near displace*
#24 Foraminal stenosis
#25 Lateral root stenosis
#26 Radiculopathy
#27 Neurogenic claudication
#28 Sagittal balance
#29 (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28)
#30 Back surgery
#31 Spin* surgery
#32 Lumbar surgery
#33 MeSH descriptor Spinal Fusion explode all trees
#34 Spin* near fusion
#35 Lumbar near fusion
#36 MeSH descriptor Decompression, Surgical explode all trees
#37 Spin* near decompress*
#38 Lumbar near decompress*
#39 Root near decompress*
#40 Fusion near decompress*

#41 Nerve near decompress*
#42 MeSH descriptor Nerve Compression Syndromes explode all trees
#43 MeSH descriptor Constriction, Pathologic explode all trees
#44 MeSH descriptor Laminectomy explode all trees
#45 Laminectomy
#46 MeSH descriptor Diskectomy explode all trees
#47 Discectomy
#48 Diskectomy
#49 Microdiscectomy
#50 Microdiskectomy
#51 Foraminotomy
#52 MeSH descriptor Foraminotomy explode all trees
#53 Spin* fixation
#54 Spin* stabili*
#55 Surgery
#56 (#30 OR #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 OR #48 OR #49 OR #50 OR #51 OR #52 OR #53 OR #54 OR #55)
#57 MeSH descriptor Physical Therapy Specialty explode all trees
#58 Physiotherap*
#59 Physical therap*
#60 (#57 OR #58 OR #59)
#61 (#29 AND #56 AND #60)

MEDLINE Search Strategy

1. Back surgery.mp.
2. Spin* surgery.mp.
3. Lumbar surgery.mp.
4. Spinal Fusion/
5. Spin* fusion.mp.
6. (lumbar adj2 fusion).mp.
7. Decompression, Surgical/
8. (spin* adj2 decompress*).mp.
9. (lumbar adj2 decompress*).mp.
10. (root adj2 decompress*).mp.
11. (fusion adj2 decompress*).mp.
12. (nerve adj2 decompress*).mp.
13. Nerve Compression Syndromes/
14. Constriction, Pathologic/
15. Laminectomy/
16. Laminectomy.mp.
17. Diskectomy/
18. Discectomy.mp.
19. Diskectomy.mp.
20. Microdiscectomy.mp.
21. Microdiskectomy.mp.
22. Foraminotomy/
23. Foraminotomy.mp.
24. Spin* fixation.mp.
25. Spin* stabilis*.mp.
26. Surgery.mp.

27. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26
28. Spinal Diseases/
29. Back Pain/
30. Low Back Pain/
31. Back pain.mp.
32. Backache.mp.
33. Dorsalgia.mp.
34. Lumbar pain.mp.
35. Coccyx.mp.
36. Coccydynia.mp.
37. Sciatica/
38. Sciatic*.mp.
39. Spondylosis/
40. Spondylolisthesis/
41. Spondylo*.mp.
42. Lumbago.mp.
43. Lumbar Vertebrae/
44. Intervertebral Disc/
45. Intervertebral Disc Degeneration/
46. Intervertebral Disc Displacement/
47. Dis* degenerat*.mp.
48. Dis* prolapse.mp.
49. Dis* herniat*.mp.
50. Arachnoiditis/
51. Spinal Stenosis/
52. (lumbar adj3 stenosis).mp.
53. (spin* adj3 stenosis).mp.
54. foraminal stenosis.mp.
55. Lateral root stenosis.mp.
56. Radiculopathy/
57. Sciatic Neuropathy/
58. Neurogenic claudication.mp.
59. Sagittal balance.mp.
60. 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59
61. randomized controlled trial/
62. controlled clinical trial/
63. randomized.ab.
64. placebo.ab,ti.
65. drug therapy.fs.
66. randomly.ab,ti.
67. trial.ab,ti.
68. groups.ab,ti.
69. 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68
70. (animals not (animals and humans)).sh.
71. 69 not 70
72. limit 71 to english language
73. Physical Therapy Specialty/
74. Physiotherap*.mp.

75. Physical therap*.mp.
76. 73 or 74 or 75
77. 27 and 60 and 72 and 76

EMBASE Search Strategy
1. clinical article/
2. exp clinical study/
3. clinical trial/
4. controlled study/
5. randomized controlled trial/
6. major clinical study/
7. double blind procedure/
8. multicenter study/
9. single blind procedure/
10. phase 3 clinical trial/
11. phase 4 clinical trial/
12. crossover procedure/
13. placebo/
14. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13
15. allocat*.mp.
16. assign*.mp.
17. blind*.mp.
18. (clinic* adj25 (study or trial)).mp.
19. compar*.mp.
20. control*.mp.
21. cross?over.mp.
22. factorial*.mp.
23. follow?up.mp.
24. placebo*.mp.
25. prospectiv*.mp.
26. random*.mp.
27. ((singl* or doubl* or trebl* or tripl*) adj25 (blind* or mask*)).mp.
28. trial.mp.
29. (versus or vs).mp.
30. 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29
31. 14 and 30
32. human/
33. nonhuman/
34. exp animal/
35. animal experiment/
36. 33 or 34 or 35
37. 32 not 36
38. 31 not 36
39. 37 and 38
40. 38 or 39
41. physiotherapy/
42. Physiotherap*.mp.
43. Physical therap*.mp.
44. 41 or 42 or 43
45. lumbar spine/

46. lumbar vertebra/
47. spine disease/
48. exp backache/
49. leg pain/
50. vertebral canal stenosis/
51. exp intervertebral disk disease/
52. intervertebral disk/
53. spondylolisthesis/
54. spondylosis/
55. spondylolysis/
56. radiculopathy/
57. "nerve root compression"/
58. ischialgia/
59. sciatic neuropathy/
60. sciatic*.mp.
61. Dis* degenerat*.mp.
62. Dis* prolapse.mp.
63. Dis* hernia*.mp.
64. (lumbar adj3 stenosis).mp.
65. (spin* adj3 stenosis).mp.
66. Lateral root stenosis.mp.
67. Foraminal stenosis.mp.
68. Neurogenic claudication.mp.
69. Sagittal balance.mp.
70. 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69
71. exp spine surgery/
72. decompression surgery/
73. nerve decompression/
74. spinal cord decompression/
75. surgery.mp. or surgery/
76. degenerative disease/su [Surgery]
77. "nerve root compression"/su [Surgery]
78. Back surgery.mp.
79. Spin* surgery.mp.
80. Lumbar surgery.mp.
81. Spin* fusion.mp.
82. (lumbar adj2 fusion).mp.
83. (spin* adj2 decompress*).mp.
84. (lumbar adj2 decompress*).mp.
85. (root adj2 decompress*).mp.
86. (nerve adj2 decompress*).mp.
87. (fusion adj2 decompress*).mp.
88. Laminectomy.mp.
89. Discectomy.mp.
90. Diskectomy.mp.
91. Microdiskectomy.mp.
92. Microdiscectomy.mp.
93. foraminotomy/
94. foraminotomy.mp.
95. Spin* fixation.mp.

96. Spin* stabilis*.mp.
97. 71 or 72 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 or 88 or 89 or 90 or 91 or 92 or 93 or 94 or 95 or 96
98. 40 and 44 and 70 and 97
99. limit 98 to english language

CINAHL Search Strategy

S82 S25 and S29 and S54 and S81
S81 S55 or S56 or S57 or S58 or S59 or S60 or S61 or S62 or S63 or S64 or S65 or S66 or S67 or S68 or S69 or S70 or S71 or S72 or S73 or S74 or S75 or S76 or S77 or S78 or S79 or S80
S80 Spin* stabilis*
S79 Spin* fixation
S78 "Foraminotomy"
S77 Microdiskectomy
S76 Microdiscectomy
S75 Diskectomy
S74 Discectomy
S73 (MH "Diskectomy")
S72 Laminectomy
S71 (MH "Laminectomy")
S70 (MH "Constriction, Pathologic")
S69 (MH "Nerve Compression Syndromes")
S68 Fusion W2 decompress*
S67 Root W2 decompress*
S66 Nerve W2 decompress*
S65 Lumbar decompress*
S64 Spin* decompress*
S63 (MH "Decompression, Surgical")
S62 Lumbar W2 fusion
S61 Spin* fusion
S60 (MH "Spinal Fusion")
S59 Spinal fusion
S58 Lumbar surgery
S57 Back surgery
S56 Spin* surgery
S55 (MH "Surgery, Operative+")
S54 S30 or S31 or S32 or S33 or S34 or S35 or S36 or S37 or S38 or S39 or S40 or S41 or S42 or S43 or S44 or S45 or S46 or S47 or S48 or S49 or S50 or S51 or S52 or S53
S53 Sagittal balance
S52 Neurogenic claudication
S51 (MH "Radiculopathy")
S50 Lateral root stenosis
S49 Foraminal stenosis
S48 Spinal W3 stenosis
S47 Lumbar W3 stenosis
S46 Dis* hernia*
S45 Dis* prolapse
S44 Dis* degenerat*
S43 Spondylo*

S42 Sciatic*
S41 (MH "Sciatica")
S40 Lumbar pain
S39 Backache
S38 Back pain
S37 (MH "Low Back Pain")
S36 (MH "Back Pain")
S35 (MH "Spondylosis+")
S34 (MH "Intervertebral Disk Displacement")
S33 (MH "Intervertebral Disk")
S32 (MH "Spinal Stenosis")
S31 (MH "Spinal Diseases")
S30 (MH "Lumbar Vertebrae")
S29 S26 or S27 or S28
S28 Physical therap*
S27 Physiotherap*
S26 (MH "Physical Therapy")
S25 S24 Limiters - English Language
S24 S22 NOT S23
S23 (MH "Animals")
S22 S1 or S2 or S3 or S4 or S5 or S6 or S7 or S8 or S9 or S10 or S11 or S12 or S13 or S14 or S15 or S16 or S17 or S18 or S19 or S20 or S21
S21 volunteer*
S20 prospectiv*
S19 control*
S18 followup stud*
S17 follow-up stud*
S16 (MH "Prospective Studies+")
S15 (MH "Evaluation Research+")
S14 (MH "Comparative Studies")
S13 latin square
S12 (MH "Study Design+")
S11 (MH "Random Sample")
S10 random
S9 placebo
S8 (MH "Placebos")
S7 (MH "Placebo Effect")
S6 triple-blind
S5 double-blind
S4 single-blind
S3 clinical W3 trial
S2 "randomi?ed controlled trial*"
S1 (MH "Clinical Trials+")

PEDRO Search Strategy
Abstract & Title: Surg*
AND Body Part: lumbar spine, sacro-iliac joint or pelvis
AND Method: clinical trial

Appendix IV: Physiotheraputic interventions before and after surgery for degenerative lumbar conditions: a systematic review (Chapter 2): Figures and Tables

Figure 1. Study selection flow diagram

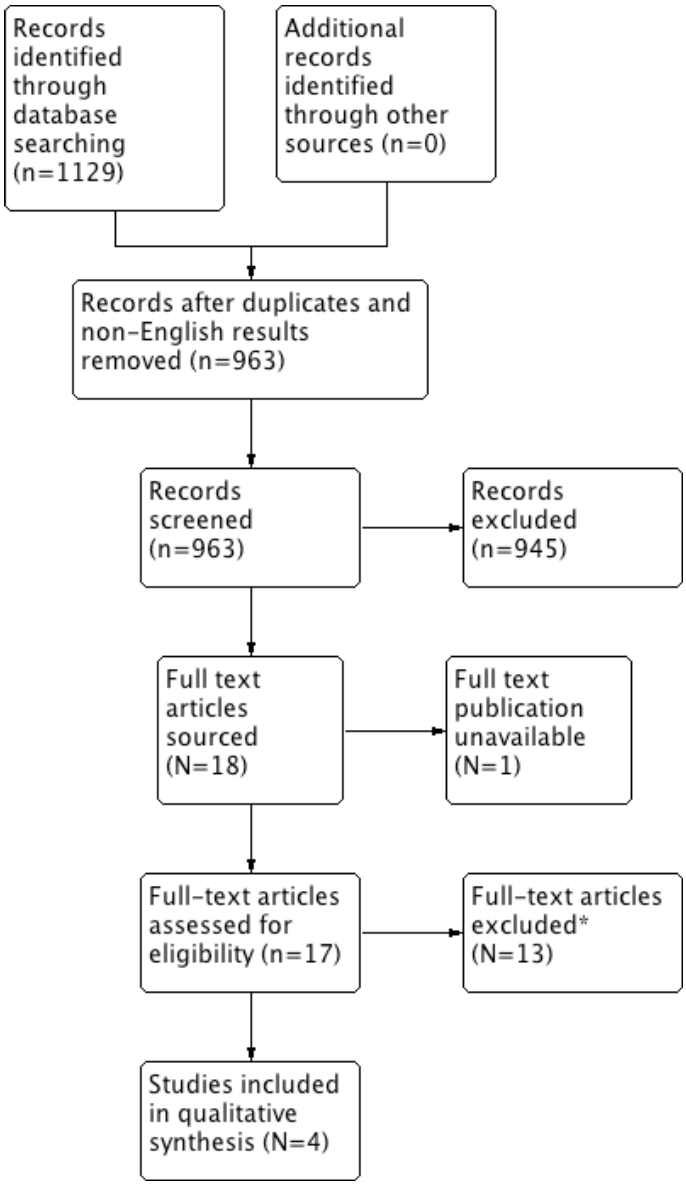


Figure 2: Treatment effect estimation (standard mean difference) – back specific functional status

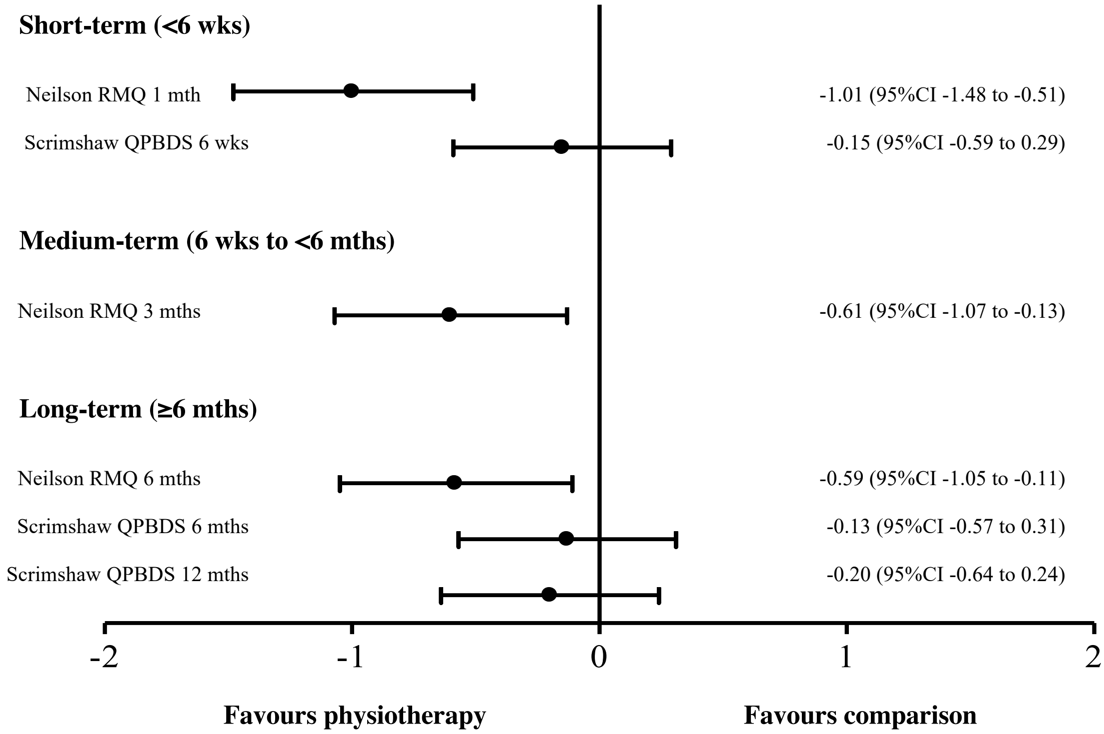


Table 1: Characteristics of studies

Study	Setting	Condition (Diagnostic criteria)	Surgical Intervention	Sample size	Age (years)	Sex (%F)	Follow-up period	Outcomes
Newsome et al. (2009)	Orthopaedic spinal unit (UK)	Single level disc prolapse (MRI consistent with symptoms)	Microdiscectomy	30	Int: 38 Con: 37	Int: 54 Con: 27	Inpatient period	Time to independent mobility Time to meeting discharge criteria
							3 months	ODI VAS SF-MPQ RTW
Nielsen et al. (2010)	Orthopaedic surgery department (Denmark)	Degenerative disc disease (Low back and radiating pain, no additional diagnostic criteria provided)	Fusion, decompression, disc replacement; maximum two levels	60	Int: 48 Con: 52	Int: 61 Con: 59	Inpatient period	Achievement of milestones
							1 month	Complications Adverse events Patient satisfaction
							6 months	BPI RMQ TUG STS 15D
Scrimshaw and Mayer (2001)	Inpatient neurological service (Australia)	Lumbar degenerative disease (No additional diagnostic criteria provided)	Discectomy, laminectomy, fusion	81	Int: 55 Con: 59	Int: 43 Con: 33	6 weeks	SLR
							12 months	GPE VAS (current) VAS (previous 24 hours) MPQ QPBDS RTW Return to normal activity
Palmer (1989)	Inpatient neurosurgical service (Canada)	Herniated lumbar disc (No additional diagnostic criteria provided)	Discectomy, foraminotomy, laminectomy, laminotomy	60	Int 1: 39 Int 2: 41	Int 1: 32 Int 2: 48	3 days	Transfer ability VAS Analgesic intake
							3 months	ODI

Int, intervention group; Con, Control Group; ODI, Oswestry Disability Index; VAS, Visual analogue scale; SF-MPQ, Short form McGill Pain Questionnaire; RTW, Return to Work; BPI, Brief Pain Inventory; RMQ, Rowland Morris Questionnaire; TUG, Timed Up and Go; STS, Sit to Stand; 15D, 15D instrument; SLR, Straight leg raise; GPE, Global Perceived Effect; MPQ, McGill Pain Questionnaire; QPBDS, Quebec Back Pain Disability Questionnaire.

Table 2: Summary of intervention

Study	Overview of Intervention	Standard Care		Physiotherapy Intervention		Co-intervention	
		Pre-operative	Post-operative	Pre-operative	Post-operative	Pre-operative	Post-operative
Newsome et al. (2009)	Early exercise in addition to standard care	-	Mobilised 4-5 hours post surgery; standard exercise and advice sheets; OP FU offered at 4 weeks if indicated	-	*Intervention:* Standard care; hip/knee flexion exercises commenced 2 hours post surgery *Control:* Standard care only	-	-
Nielsen et al. (2010)	Prehabilitation and early rehabilitation in addition to standard care	-	Mobilisation the day of surgery; 30 mins daily training.	*Intervention:* HEP commenced 6-8 weeks prior to surgery *Control:* -	*Intervention:* Standard care; additional 30mins daily training *Control:* Standard care only	*Intervention:* Nutritional supplementation *Control:* -	*Intervention:* Nutritional supplementation; Epidural PCA *Control:* Epidural infusion
Scrimshaw and Mayer (2001)	Neural mobilisation exercise in addition to standard care	-	LL and trunk exercises; HEP	-	*Intervention:* Standard care; neural mobilisation exercises *Control:* Standard care only	-	-
Palmer (1989)	Comparison of two transfer methods, in addition to standard care	Assessment and explanation of post-operative care	Deep breathing and coughing exercises; mobilisation; stationary bicycle; stairs; HEP; education	*Intervention A:* Standard care *Intervention B:* Standard care	*Intervention A:* Standard care; prone transfer method *Intervention B:* Standard care; side-lying transfer method	-	-

OP, outpatient; FU, follow-up; HEP, home exercise program; PCA, patient controlled analgesia; LL, lower limb.

Table 3 - Risk of bias summary as assessed by a modified version of the Cochrane Collaboration tool [11]

	Random sequence generation	Allocation concealment	Blinding of patients	Blinding of care providers	Blinding of assessors	Incomplete outcome data	Intention to treat analysis	Selective reporting	Baseline similarity	Co-interventions	Compliance	Timing of outcome assessment
Newsome et al. (2009)	L	U	H	H	H	L	U	H	U	L	U	L
Nielsen et al. (2010)	L	L	H	H	H	L	L	H	L	H	L	L
Scrimshaw and Mayer (2001)	L	U	H	H	H	L	H	L	L	L	U	L
Palmer (1989)	L	U	H	H	H	L	L	L	L	L	L	L

L, low risk; U, unclear risk; H, high risk.

Table 4: Summary of findings – Patient outcome following provision of an additional physiotherapy intervention to standard care

	Summary of findings			Factors influencing the quality of evidence					Level of evidence (GRADE)
Outcomes	Newsome (2009)	Nielsen (2010)	Scrimshaw and Mayer (2001)	Design and implementation	Indirectness	Inconsistency of results	Imprecision	Publication bias	
Pain	NSD	Significantly less pain and less low back pain intensity (BPI)[a]. NSD in any other pain score.	NSD	-1[b]	-1[c]	Nil	-1[d,e]	Nil	Very low
Back specific functional status	NSD	NSD	NSD	-1[b]	-1[c]	Nil	-1[d,e]	Nil	Very low
General functional status	More rapid achievement of independent mobility. Significantly faster RTW. NSD in achievement of independent mobility or meeting all discharge criteria at 15 hours after surgery.	More rapid achievement of all functional milestones. Significantly earlier discharge from hospital. NSD in achievement of individual functional milestones, TUG or STS scores.	NSD	-1[b]	-1[c]	Nil	-1[d]	Nil	Very low
Quality of life	-	NSD	-	N/A	N/A	N/A	N/A	N/A	N/A
Patient satisfaction	-	Significantly more patients in the intervention group very satisfied with treatment.	-	N/A	N/A	N/A	N/A	N/A	N/A
Adverse events	-	NSD	-	N/A	N/A	N/A	N/A	N/A	N/A

NSD, no significant difference; RTW, return to work; BPI, Brief Pain Inventory; TUG, Timed Up and Go; STS, Sit to Stand; N/A, not applicable, outcome reported by a single trial only. [a]Unclear how this result was measured or which time points it related to; [b]Unclear risk of bias (Newsome) and/or significant co-intervention potentially leading to performance bias (Nielson); [c]Heterogeneity of interventions assessed and/or outcome measures used; [d]Single trial/small sample size; [e]Incomplete reporting of data in one or more study, unable to calculate effect size

Table 5: Summary of findings - Comparison of two transfer methods

Study	Outcomes					
	Pain	Back Specific Functional Status	General Functional Status	Quality of Life	Patient Satisfaction	Adverse Events
Palmer (1989)	Significantly less pain during prone transfers D1 post-operatively. NSD at any other measured time points.	NSD	NSD	-	-	-

NSD, no significant difference.

Appendix V: Physiotherapy management of patients undergoing lumbar spinal surgery for degenerative conditions: a survey of Australian physiotherapists (Chapter 3): Telephone Questionnaire

General Information

The following set of questions are designed to provide us with some general information about the hospital you work in, the type of lumbar surgeries performed, and your own experience.

1. How many years have you been practicing as a physiotherapist? ______________________________

2. How many years have you been working with patients following lumbar surgery? _____________

3. Do you work in a public or a private hospital?
   - ☐ Public hospital
   - ☐ Private hospital

4. How many fulltime equivalent physiotherapists are employed in your hospital? ______________

5. Which of the following best describes the structure of the physiotherapy service in your hospital?
   a) One physiotherapy service, employed directly by the hospital
   b) One physiotherapy service, employed by an external company
   c) More than one physiotherapy service, employed by an external company

   If yes - How many separate companies provide physiotherapy services to patients undergoing spinal surgery? _________________

6. On average, how many patients undergo lumbar surgery per week in your hospital?
   - ☐ Less than 1 ***(cut off point)***
   - ☐ 1 – 5
   - ☐ 6 – 10
   - ☐ 11 – 15
   - ☐ 15 – 20
   - ☐ 21 or greater

7. Of the patients undergoing lumbar surgery, approximately what proportion of patients undergo the following surgical procedures? (Note - This answer may add up to more than 100% due to multiple procedures being performed on a single patient)

	None	1-25%	26-50%	51-75%	76-100%
• Micro-discectomy	☐	☐	☐	☐	☐
• Discectomy	☐	☐	☐	☐	☐
• Laminectomy	☐	☐	☐	☐	☐
• Fusion	☐	☐	☐	☐	☐

Surgeon Information

8. Who performs lumbar spinal surgery in your hospital – neurosurgeons, orthopaedic surgeons or both?

   ☐ Neurosurgeons
   - How many neurosurgeons currently perform lumbar surgery at your hospital?
     ____

   ☐ Orthopaedic surgeons
   - How many orthopaedic surgeons currently perform lumbar surgery at your hospital?
     ____

9. Does the routine physiotherapy intervention, including advice and education, mobility and functional tasks, exercise and onward referral vary between surgeons?

   ☐ Yes **Complete the following section for each surgeon**
   ☐ No **Complete the following section once**

If yes **The following questions are about the physiotherapy service and intervention provided at your hospital.**

I will ask the following set of questions in relation to one surgeon at a time, however we will only repeat the question where there is variation in physio intervention between the surgeons.

3 + **To make this process clear, I recommend you write down a list of the surgeons and assign each a code such as a number or initial. The first surgeon we discuss will be used as a reference point, so I suggest you choose a surgeon with the least variation from your routine practice to discuss first.**

Also **I will be asking about variations in physio practice between the types of surgical procedures – specifically laminectomy, fusion, discectomy and micro-discectomy.**

Physiotherapy Intervention

Surgeon #: **One**

Provision of physiotherapy service

10. How many patients are seen by a physiotherapist?

		None	Some	All
a)	Prior to undergoing lumbar surgery	☐	☐	☐
b)	Following lumbar surgery	☐	☐	☐

11. Is there any variation in whether patients are seen based on the type of surgical procedure the patient has had?

☐ **Yes** **(complete below)**
☐ **No** **(go to next section)**

12. How many patients are seen by a physiotherapist **prior** to undergoing a:

		None	Some	All
a)	Micro-discectomy	☐	☐	☐
b)	Discectomy	☐	☐	☐
c)	Laminectomy	☐	☐	☐
d)	Fusion	☐	☐	☐

13. How many patients are seen by a physiotherapist **following** a:

		None	Some	All
a)	Micro-discectomy	☐	☐	☐
b)	Discectomy	☐	☐	☐
c)	Laminectomy	☐	☐	☐
d)	Fusion	☐	☐	☐

No patients seen:

14. Please indicate the how the following factors influence the decision not to see patients **prior** to surgery.

		No influence	Some influence	Strong influence
a)	Current evidence	☐	☐	☐
b)	Experience	☐	☐	☐
c)	Surgeon protocols or preferences	☐	☐	☐
d)	Pre-admission or admission process	☐	☐	☐
e)	Staffing or time limitations	☐	☐	☐

15. Please indicate the how the following factors influence the decision not to see patients **following** surgery.

		No influence	Some influence	Strong influence
a)	Current evidence	☐	☐	☐
b)	Experience	☐	☐	☐
c)	Surgeon protocols or preferences	☐	☐	☐
d)	Staffing or time limitations	☐	☐	☐

Go to: physiotherapy following discharge from the acute setting

Some patients seen:

16. What is the main reason only some patients are seen **pre**-operatively?

☐ Dependent on patient need
☐ Surgeon protocols or preferences
☐ Time or staffing limitations
☐ Other________________________

17. What is the main reason only some patients are seen **post**-operatively?

☐ Dependent on patient need
☐ Surgeon protocols or preferences
☐ Time or staffing limitations
☐ Other________________________

If yes to 13/14a):

18. Which of the following criteria are used to identify patients that require physiotherapy, either pre or post-operatively (as many as apply)?

		Pre-op	Post-op
a)	Age	☐	☐
b)	Pain	☐	☐
c)	Co-morbidities	☐	☐
d)	Mobility status	☐	☐
e)	Functional status	☐	☐
f)	Social history	☐	☐
g)	Compensation or insurance status	☐	☐
h)	Multi-level surgery	☐	☐

Some/all patients seen:

Timing and frequency of physiotherapy:

19. Is there any variation in when or how often you see patients, dependent on the type of surgical procedure the patient has had?

- ☐ **Yes** **(elaborate below/complete this section for each variation)**
- ☐ **No**

Pre-operative:

20. When are patients seen pre-operatively?

- ☐ Pre-admission – one on one
- ☐ Pre-admission – class
- ☐ Following admission to hospital

21. How many times are patients seen pre-operatively?

- ☐ Once
- ☐ Twice
- ☐ Three or more times

Post-operative:

22. How soon after surgery are patients first seen by a physiotherapist?

- ☐ Day of surgery
- ☐ Day 1
- ☐ Day 2
- ☐ Day 3 or later

23. How many times per day are patients routinely seen post-operatively?

- ☐ Once
- ☐ Twice
- ☐ Three or more times

24. How many times in total are patients seen post-operatively?

- ☐ 1 - 2
- ☐ 3 - 4
- ☐ 5 – 6
- ☐ 6 or greater

Advice and education:

25. Does the routine physiotherapy intervention include advice and education?

		Yes	No
a)	Pre-operatively	☐	☐
b)	Post-operatively	☐	☐

If yes:

26. Is there any variation in the advice or education you give to patients, including post-operative restrictions, dependent on the type of surgical procedure the patient has had?

☐ **Yes** **(elaborate below/complete this section for each variation)**
☐ **No**

27. Do you provide:

		Yes	No
•	Verbal information?	☐	☐
•	Written information?	☐	☐
•	Online information?	☐	☐
•	Video resources?	☐	☐

28. Are any of the following restrictions applied to this surgeon's patients?

		Yes	**No**	**Unsure**	Up to 2	2-4	4-6	6-8	8+	**Comments/variation between surgeries**
a)	Movement restrictions	☐	☐	☐						
	i) Flexion	☐	☐		☐	☐	☐	☐	☐	
	ii) Extension	☐	☐		☐	☐	☐	☐	☐	
	iii) Rotation	☐	☐		☐	☐	☐	☐	☐	
b)	Lifting restrictions	☐	☐	☐	☐	☐	☐	☐	☐	
	Weight limit ___________________									
c)	Sitting restrictions	☐	☐	☐	☐	☐	☐	☐	☐	
	Duration/frequency ___________									
d)	Walking	☐	☐	☐	☐	☐	☐	☐	☐	
	Distance ______________________									
e)	Return to work	☐	☐	☐	☐	☐	☐	☐	☐	
f)	Resuming usual activity	☐	☐	☐	☐	☐	☐	☐	☐	
g)	Resuming driving	☐	☐	☐	☐	☐	☐	☐	☐	
h)	Resuming sex	☐	☐	☐	☐	☐	☐	☐	☐	

Mobility and functional tasks:

29. Does the routine physiotherapy intervention include training of mobility and functional tasks?

		Yes	No
a)	Pre-operatively	☐	☐
b)	Post-operatively	☐	☐

If yes:

30. Is there any variation in the mobility or functional task training you provide, dependent on the type of surgical procedure the patient has had?

☐ **Yes** **(elaborate below/complete this section for each variation)**
☐ **No**

31. Does this include:

		Pre-op	Post-op
a)	Getting in and out of bed	☐	☐
b)	Getting in and out of a chair	☐	☐
c)	Ambulation	☐	☐
d)	Stairs	☐	☐
e)	Other ___________________________________	☐	☐

32. How soon after surgery are patients first allowed to mobilise?

☐ Day of surgery
☐ Day 1
☐ Day 2
☐ Day 3 or later

Exercise:

33. Does the routine physiotherapy intervention include exercise?

☐ Yes (Complete below)
☐ No

34. Please describe each exercise

	Pre-op	**Post-op**	**When does this exercise commence post-op?** D0	D1	D2+	**Surgical procedure** All	Micro	Disc	Lami	Fusion
Spinal range of motion										
☐ Flexion	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Extension	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Rotation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Stability										
☐ Transverse abdominus	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Multifidus	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Gluts	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Strengthening										
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Neural mobilization										
☐ Sciatic nerve	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Stretching										
☐ Calves	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Hamstrings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cardiovascular training										
☐ Walking	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Cycling	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Swimming	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Pre-operatively:

35. Which of the following best describes the main purpose of commencing exercise pre-operatively?

☐ To demonstrate the exercises prescribed in the post-operative setting
☐ To aid in pre-operative pain management
☐ To achieve pre-operative ROM, stability, or strength gains
☐ To maximize pre-operative function

Physiotherapy following discharge from the acute setting:

Inpatients:

36. How many patients are referred for ongoing **inpatient** rehabilitation?
    - ☐ None
    - ☐ Some
    - ☐ All

37. Does referral to inpatient rehabilitation depend on the surgical procedure the patient has had?
- ☐ **Yes**
  Which surgical procedures are routinely referred?
  - ☐ Micro-discectomy
  - ☐ Discectomy
  - ☐ Laminectomy
  - ☐ Fusion
- ☐ **No**

38. Please rate how each of the following factors influence the decision to refer patients to **inpatient** rehabilitation:

		No influence	Some influence	Strong influence
a)	Patient need	☐	☐	☐
b)	Current evidence or research	☐	☐	☐
c)	Personal experience	☐	☐	☐
d)	Surgeon protocols or preferences	☐	☐	☐
e)	Patient expectations	☐	☐	☐
f)	Organisational expectations	☐	☐	☐
g)	Other ____________________________	☐	☐	☐

Outpatients:

39. How many patients are referred for ongoing **outpatient** physiotherapy or rehabilitation?
    - ☐ None
    - ☐ Some
    - ☐ All

40. Does referral to outpatient physiotherapy or rehabilitation depend on the surgical procedure the patient has had?
- ☐ **Yes**
  Which surgical procedures are routinely referred?
  - ☐ Micro-discectomy
  - ☐ Discectomy
  - ☐ Laminectomy
  - ☐ Fusion
- ☐ **No**

41. ***If some/all -*** When patients are referred for **outpatient** physiotherapy, when does it generally commence?
    - ☐ Within 2 weeks following discharge
    - ☐ 2 – 6 weeks following discharge
    - ☐ 7 weeks or greater
    - ☐ Variable dependent on patient need

42. Please rate how each of the following factors influence the decision to refer patients to **outpatient** physiotherapy:

		No influence	Some influence	Strong influence
a)	Patient need	☐	☐	☐
b)	Current evidence or research	☐	☐	☐
c)	Personal experience	☐	☐	☐
d)	Surgeon protocols or preferences	☐	☐	☐
e)	Patient expectations	☐	☐	☐
f)	Organisational expectations	☐	☐	☐
g)	Other ____________________________	☐	☐	☐

Outcome Measurement:

43. Are any of the following outcome measures routinely used, by any member of the multidisciplinary team, either pre or post operatively?

	No	Yes - Pre-op	Yes - Post op	**Comments/Variations**
• Spinal range of motion	☐	☐	☐	
• Straight leg raise	☐	☐	☐	
• Pain - visual analogue scale	☐	☐	☐	
• McGill pain questionnaire	☐	☐	☐	
• Timed up and go	☐	☐	☐	
• Sit to stand	☐	☐	☐	
• 10 metre walk test	☐	☐	☐	
• 6-minute walk test	☐	☐	☐	
• Oswestry Disability Index	☐	☐	☐	
• Roland Morris Questionnaire	☐	☐	☐	
• Quebec Back Pain Disability Q.	☐	☐	☐	
• Patient satisfaction	☐	☐	☐	
• SF-36	☐	☐	☐	

44. How are the outcome measures used?

☐ Feedback to patients
☐ Treatment provision/progression
☐ Discharge planning
☐ Onward referral
☐ Other ____

Provision of physiotherapy service

45. How many patients are seen by a physiotherapist?

		None	Some	All
c)	Prior to undergoing lumbar surgery	☐	☐	☐
d)	Following lumbar surgery	☐	☐	☐

46. Is there any variation in whether patients are seen based on the type of surgical procedure the patient has had?

☐ **Yes** **(complete below)**
☐ **No** **(go to next section)**

47. How many patients are seen by a physiotherapist **prior** to undergoing a:

		None	Some	All
e)	Micro-discectomy	☐	☐	☐
f)	Discectomy	☐	☐	☐
g)	Laminectomy	☐	☐	☐
h)	Fusion	☐	☐	☐

48. How many patients are seen by a physiotherapist **following** a:

		None	Some	All
e)	Micro-discectomy	☐	☐	☐
f)	Discectomy	☐	☐	☐
g)	Laminectomy	☐	☐	☐
h)	Fusion	☐	☐	☐

No patients seen:

49. Please indicate the how the following factors influence the decision not to see patients **prior** to surgery.

		No influence	Some influence	Strong influence
a)	Current evidence	☐	☐	☐
b)	Experience	☐	☐	☐
c)	Surgeon protocols or preferences	☐	☐	☐
d)	Pre-admission or admission process	☐	☐	☐
e)	Staffing or time limitations	☐	☐	☐

50. Please indicate the how the following factors influence the decision not to see patients **following** surgery.

		No influence	Some influence	Strong influence
a)	Current evidence	☐	☐	☐
b)	Experience	☐	☐	☐
c)	Surgeon protocols or preferences	☐	☐	☐
d)	Staffing or time limitations	☐	☐	☐

Some patients seen:

51. What is the main reason only some patients are seen **pre**-operatively?

☐ Dependent on patient need
☐ Surgeon protocols or preferences
☐ Time or staffing limitations
☐ Other________________________

52. What is the main reason only some patients are seen **post**-operatively?

☐ Dependent on patient need
☐ Surgeon protocols or preferences
☐ Time or staffing limitations
☐ Other________________________

If yes to 13/14a):

53. Which of the following criteria are used to identify patients that require physiotherapy, either pre or post-operatively (as many as apply)?

		Pre-op	Post-op
i)	Age	☐	☐
j)	Pain	☐	☐
k)	Co-morbidities	☐	☐
l)	Mobility status	☐	☐
m)	Functional status	☐	☐
n)	Social history	☐	☐
o)	Compensation or insurance status	☐	☐
p)	Multi-level surgery	☐	☐

Timing and frequency of physiotherapy:

54. Is there any variation in when or how often you see patients, dependent on the type of surgical procedure the patient has had?

- ☐ **Yes** **(elaborate below/complete this section for each variation)**
- ☐ **No**

Pre-operative:

55. When are patients seen pre-operatively?

- ☐ Pre-admission – one on one
- ☐ Pre-admission – class
- ☐ Following admission to hospital

56. How many times are patients seen pre-operatively?

- ☐ Once
- ☐ Twice
- ☐ Three or more times

Post-operative:

57. How soon after surgery are patients first seen by a physiotherapist?

- ☐ Day of surgery
- ☐ Day 1
- ☐ Day 2
- ☐ Day 3 or later

58. How many times per day are patients routinely seen post-operatively?

- ☐ Once
- ☐ Twice
- ☐ Three or more times

59. How many times in total are patients seen post-operatively?

- ☐ 1 - 2
- ☐ 3 - 4
- ☐ 5 – 6
- ☐ 6 or greater

Advice and education:

60. Does the routine physiotherapy intervention include advice and education?

		Yes	No
c)	Pre-operatively	☐	☐
d)	Post-operatively	☐	☐

If yes:

61. Is there any variation in the advice or education you give to patients, including post-operative restrictions, dependent on the type of surgical procedure the patient has had?

☐ **Yes** **(elaborate below/complete this section for each variation)**
☐ **No**

62. Do you provide:

	Yes	No
• Verbal information?	☐	☐
• Written information?	☐	☐
• Online information?	☐	☐
• Video resources?	☐	☐

63. Are any of the following restrictions applied to this surgeon's patients?

	Yes	**No**	**Unsure**	Up to 2	2-4	4-6	6-8	8+	**Comments/variation between surgeries**
a) Movement restrictions	☐	☐	☐						
i) Flexion	☐	☐		☐	☐	☐	☐	☐	
ii) Extension	☐	☐		☐	☐	☐	☐	☐	
iii) Rotation	☐	☐		☐	☐	☐	☐	☐	
b) Lifting restrictions	☐	☐	☐	☐	☐	☐	☐	☐	
Weight limit ___________________									
c) Sitting restrictions	☐	☐	☐	☐	☐	☐	☐	☐	
Duration/frequency ___________									
d) Walking	☐	☐	☐	☐	☐	☐	☐	☐	
Distance _______________________									
e) Return to work	☐	☐	☐	☐	☐	☐	☐	☐	
f) Resuming usual activity	☐	☐	☐	☐	☐	☐	☐	☐	
g) Resuming driving	☐	☐	☐	☐	☐	☐	☐	☐	
h) Resuming sex	☐	☐	☐	☐	☐	☐	☐	☐	

Mobility and functional tasks:

64. Does the routine physiotherapy intervention include training of mobility and functional tasks?

		Yes	No
a)	Pre-operatively	☐	☐
b)	Post-operatively	☐	☐

If yes:

65. Is there any variation in the mobility or functional task training you provide, dependent on the type of surgical procedure the patient has had?

☐ **Yes** **(elaborate below/complete this section for each variation)**
☐ **No**

66. Does this include:

		Pre-op	Post-op
f)	Getting in and out of bed	☐	☐
g)	Getting in and out of a chair	☐	☐
h)	Ambulation	☐	☐
i)	Stairs	☐	☐
j)	Other ____________________________________	☐	☐

Exercise:

67. Does the routine physiotherapy intervention include exercise?

☐ Yes (Complete below)
☐ No

68. Please describe each exercise

Exercise	**Pre-op**	**Post-op**	**When does this exercise commence post-op?** D0	D1	D2+	**Surgical procedure** All	Micro	Disc	Lami	Fusion
Spinal range of motion										
☐ Flexion	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Extension	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Rotation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Stability										
☐ Transverse abdominus	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Multifidus	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Gluts	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Strengthening										
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Neural mobilization										
☐ Sciatic nerve	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Stretching										
☐ Calves	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Hamstrings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cardiovascular training										
☐ Walking	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Cycling	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ Swimming	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
☐ ____________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Pre-operatively:

69. Which of the following best describes the main purpose of commencing exercise pre-operatively?

☐ To demonstrate the exercises prescribed in the post-operative setting
☐ To aid in pre-operative pain management
☐ To achieve pre-operative ROM, stability, or strength gains
☐ To maximize pre-operative function

Physiotherapy following discharge from the acute setting:

Inpatients:

70. How many patients are referred for ongoing **inpatient** rehabilitation?
    - ☐ None
    - ☐ Some
    - ☐ All

71. Does referral to inpatient rehabilitation depend on the surgical procedure the patient has had?
- ☐ **Yes**
  Which surgical procedures are routinely referred?
  - ☐ Micro-discectomy
  - ☐ Discectomy
  - ☐ Laminectomy
  - ☐ Fusion
- ☐ **No**

72. Please rate how each of the following factors influence the decision to refer patients to **inpatient** rehabilitation:

		No influence	Some influence	Strong influence
h)	Patient need	☐	☐	☐
i)	Current evidence or research	☐	☐	☐
j)	Personal experience	☐	☐	☐
k)	Surgeon protocols or preferences	☐	☐	☐
l)	Patient expectations	☐	☐	☐
m)	Organisational expectations	☐	☐	☐
n)	Other ______________________________	☐	☐	☐

Outpatients:

73. How many patients are referred for ongoing **outpatient** physiotherapy or rehabilitation?
    - ☐ None
    - ☐ Some
    - ☐ All

74. Does referral to outpatient physiotherapy or rehabilitation depend on the surgical procedure the patient has had?
- ☐ **Yes**
  Which surgical procedures are routinely referred?
  - ☐ Micro-discectomy
  - ☐ Discectomy
  - ☐ Laminectomy
  - ☐ Fusion
- ☐ **No**

75. ***If some/all -*** When patients are referred for **outpatient** physiotherapy, when does it generally commence?
    - ☐ Within 2 weeks following discharge
    - ☐ 2 – 6 weeks following discharge
    - ☐ 7 weeks or greater
    - ☐ Variable dependent on patient need

76. Please rate how each of the following factors influence the decision to refer patients to **outpatient** physiotherapy:

		No influence	Some influence	Strong influence
h)	Patient need	☐	☐	☐
i)	Current evidence or research	☐	☐	☐
j)	Personal experience	☐	☐	☐
k)	Surgeon protocols or preferences	☐	☐	☐
l)	Patient expectations	☐	☐	☐
m)	Organisational expectations	☐	☐	☐
n)	Other ______________________________	☐	☐	☐

Outcome Measurement:

77. Are any of the following outcome measures routinely used, by any member of the multidisciplinary team, either pre or post operatively?

	No	Yes - Pre-op	Yes - Post op	**Comments/Variations**
• Spinal range of motion	☐	☐	☐	
• Straight leg raise	☐	☐	☐	
• Pain - visual analogue scale	☐	☐	☐	
• McGill pain questionnaire	☐	☐	☐	
• Timed up and go	☐	☐	☐	
• Sit to stand	☐	☐	☐	
• 10 metre walk test	☐	☐	☐	
• 6-minute walk test	☐	☐	☐	
• Oswestry Disability Index	☐	☐	☐	
• Roland Morris Questionnaire	☐	☐	☐	
• Quebec Back Pain Disability Q.	☐	☐	☐	
• Patient satisfaction	☐	☐	☐	
• SF-36	☐	☐	☐	

78. How are the outcome measures used?

☐ Feedback to patients
☐ Treatment provision/progression
☐ Discharge planning
☐ Onward referral
☐ Other ____

***Complete for each surgeon* – Surgeon #: ___________________**

79. Is there any variation in the ________________________ of the routine physiotherapy between this surgeon, and the first surgeon we discussed?

	Surgeon 2	Surgeon 3	Surgeon 4	Surgeon 5	Surgeon 6	Surgeon 7	Surgeon 8	Surgeon 9	Surgeon 10	
Whether patients are seen by a physio pre or post op	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	Complete **provision of physiotherapy service** section
Timing and frequency	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Ye ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	Complete **timing and frequency** section
Advice and education	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	Complete **advice and education** section
Mobility and functional tasks	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	Complete **mobility and functional task** section
Exercise	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	Complete **exercises** section
Referral to inpatient and outpatient physio	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	Complete **physio following discharge from the acute setting** section
Outcome measurement	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	Complete **outcome measurement** section

Additional Information:

80. Do you wish to add any additional comments or information about the physiotherapy service provided at your hospital, for patients undergoing lumbar surgery?

Appendix VI: The validity of using activity monitors to detect step count after lumbar fusion surgery (Chapter 4): Figures and Tables

Figure 1. Bland Altman Plot: ActivPAL3

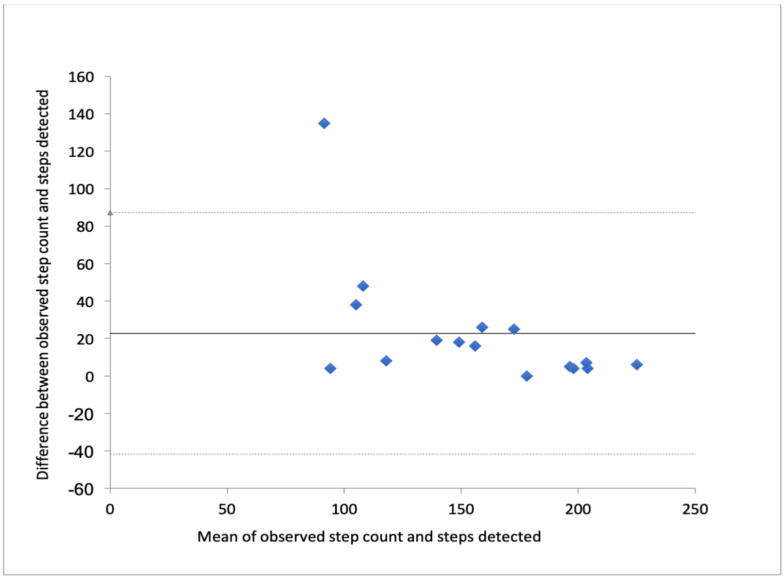
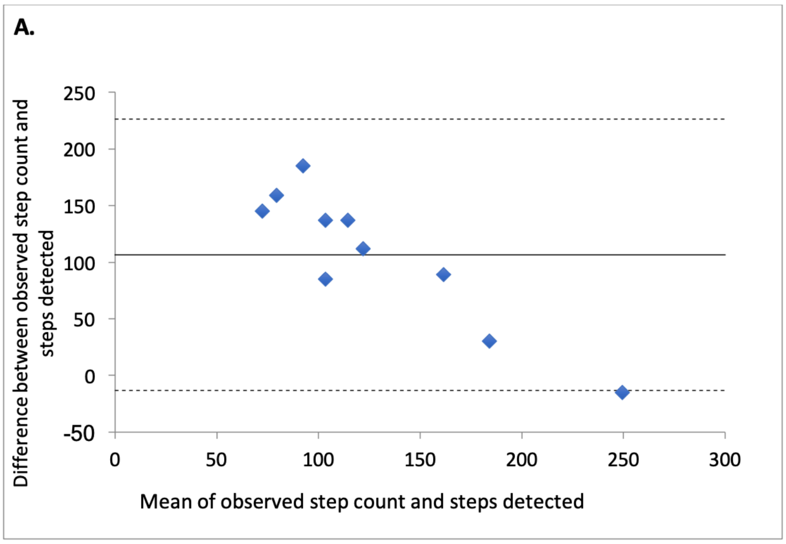
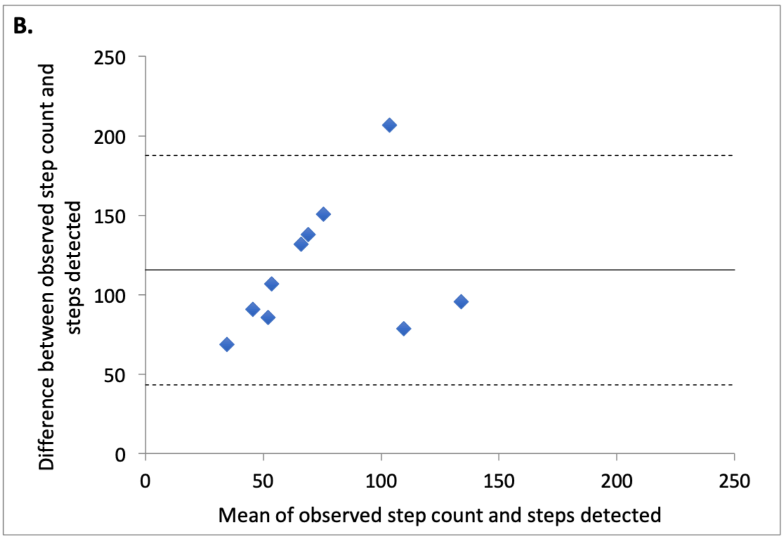


Figure 2. Bland Altman Plot: difference between observed step count and steps detected in wrist worn activity monitors with and without gait aids.

2a. Fitbit Flex (no gait aid)



2b. Fitbit Flex (with gait aid)



2c. Jawbone UP Move (no gait aid)

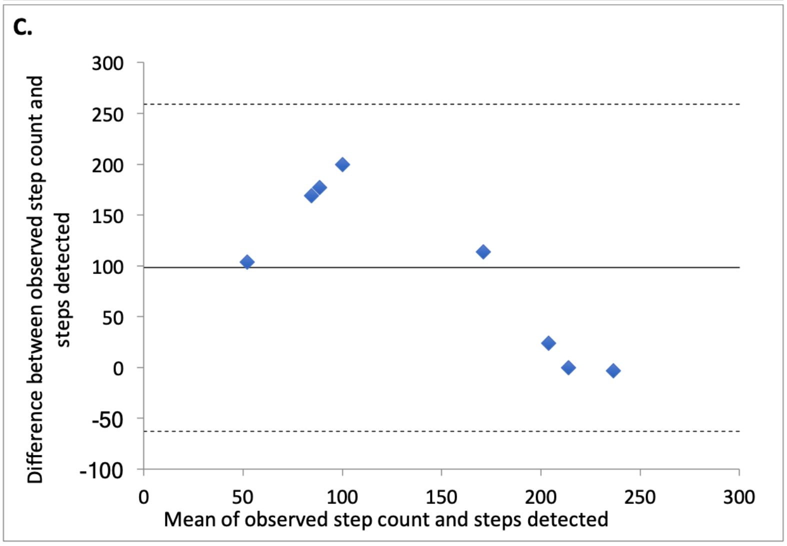
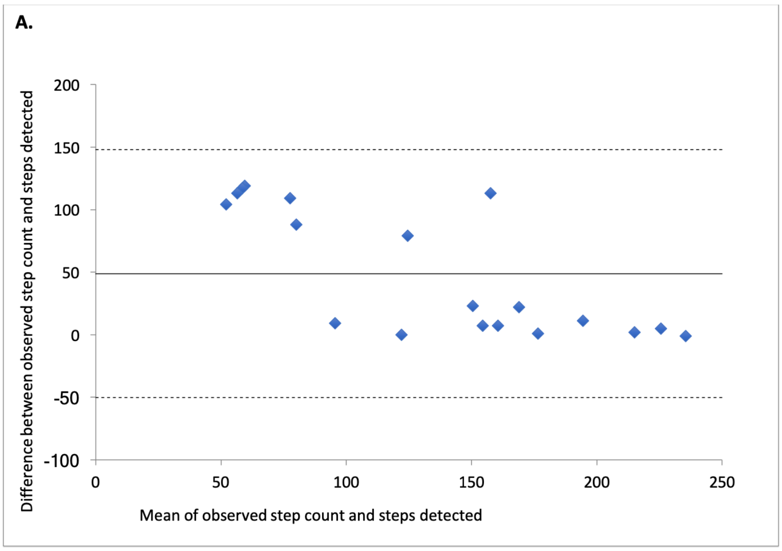


Figure 3. Bland Altman Plot: difference between observed step count and steps detected in thigh worn activity monitors.

3a. Fitbit Flex



3b. Jawbone UP Move

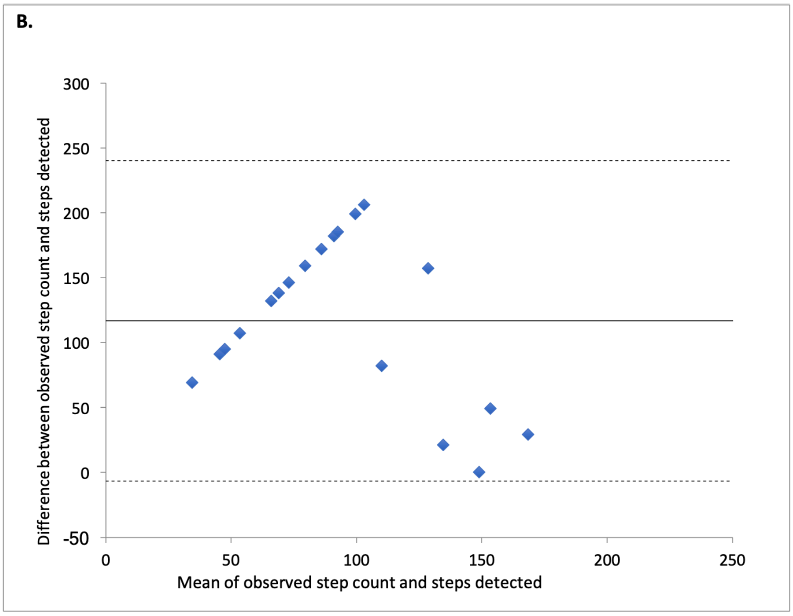


Table 1: Participant characteristics

	N	
Age		
Mean (SD)	65	(13)
18-64	13	(33%)
65+	27	(67%)
Gender		
Female	26	(65%)
Male	14	(35%)
Vertebral levels fused		
Single level	32	(80%)
Multi-level	8	(20%)
Pre-operative:		
Duration of pain (months): median (range)	24	(3-336)
Back pain*: mean (SD)	7.08	(2.42)
Leg pain*: mean (SD)	5.98	(3.35)
Day of assessment		
Post-operative day 2	24	(60%)
Post–operative day 3	16	(40%)
Gait aid during assessment		
No	18	(45%)
Yes	22	(55%)

*Numerical pain rating scale (1-10)

Table 2: Summary of Results

Activity monitor	Position		N	Observed step count: Mean (SD)	Steps detected†: Mean (SD)	PSD‡ Mean% (SD%)	SEM§	ICC (95%CI)
ActivPAL3	Thigh		17	167 (36.6)	145 (54)	85 (27)	23.2	0.81 (0.37 – 0.94)**
Fitbit Flex	Wrist	Total	20	157 (43.8)	46 (69)	24 (34)	36.2	0.35 (-0.17 – 0.74)**
		No gait aid	10	182 (29.4)	75 (84)	42 (35)	43.3	0.36 (-0.23 – 0.79)*
		Gait aid	10	132 (45.5)	17 (44)	3 (18)	26.0	0.13 (-0.10 – 0.55)
	Thigh	Total	19	159 (43.9)	110 (82)	66 (42)	35.8	0.11 (-0.15 – 0.44)
Jawbone Up Move	Wrist	Total	20	160 (42.7)	38 (81)	17 (40)	40.5	0.36 (-0.17 – 0.74)**
		No gait aid	8	193 (42.7)	95 (107)	43 (52)	58.1	0.46 (-0.36 – 0.87)
		Gait aid	12	138 (26.0)	0 (0)	0 (0)	-	-
	Thigh	Total	19	152 (40.0)	36 (58)	22 (35)	44.6	0.71 (-0.02 – 0.91)**

* $p \leq 0.05$; ** $p \leq 0.01$; †Steps detected by activity monitor; ‡Percentage of Steps Detected: activity monitor step count/observed step count; §Standard error of measurement

Table 3: Correlation between activity monitor accuracy and distance walked over two minutes

Activity monitor	Pearson Correlation Coefficient	95% CI
Total		
Fitbit Flex (N=39)	0.58**	0.33-0.76
Jawbone Up Move (N=39)	0.57**	0.31-0.75
ActivPAL3 (N=17)	0.44	-0.05-0.76
Wrist position		
Fitbit Flex		
No gait aid (N=10)	0.78**	0.30-0.95
With gait aid (N=10)	0.32	-0.38-0.79
Jawbone Up Move		
No gait aid (N= 8)	0.76*	0.12-0.95
With gait aid (N=12)	n/a[1]	
Thigh position		
Fitbit flex (N=19)	0.56*	0.14-0.81
Jawbone Up Move (N=19)	0.31	-0.17-0.67
ActivPAL3 (N=17)	0.44	-0.05-0.76

[1] Steps detected=0, unable to be calculated; * $p \le 0.05$; ** $p \le 0.01$

Table S1. Percentage of steps detected – wrist position

Activity monitor	Steps detected by activity monitor / observed step count (%)												Mean steps detected: % (SD)
Fitbit Flex													
No gait aid (N=10)	46/183 (25%)	0/145 (0%)	61/146 (42%)	257/242 (106%)	169/199 (85%)	0/159 (0%)	35/172 (20%)	117/206 (57%)	66/178 (37%)	0/185 (0%)			42% (35%)
With gait aid (N=10)	0/151 (0%)	0/107 (0%)	86/182 (47%)	0/91 (0%)	0/69 (0%)	0/138 (0%)	0/132 (0%)	0/207 (0%)	9/95 (9%)	70/149 (47%)			3% (18%)
Total (N=20)													24% (34%)
Jawbone Up Move													
No gait aid (N=8)	0/177 (0%)	0/169 (0%)	192/216 (89%)	238/235 (101%)	0/104 (0%)	214/214 (100%)	0/200 (0%)	114/228 (50%)					43% (52%)
With gait aid (N=12)	0/119 (0%)	0/117 (0%)	0/162 (0%)	0/100 (0%)	0/180 (0%)	0/122 (0%)	0/124 (0%)	0/164 (0%)	0/113 (0%)	0/158 (0%)	0/132 (0%)	0/164 (0%)	0% (0%)
Total (N=20)													17% (40%)

Table S2. Percentage of steps detected – thigh position

Activity monitor	Steps detected by activity monitor / observed step count (%)										Mean steps detected: % (SD)
Fitbit Flex											
Test 1-10	0/119 (0%)	0/117 (0%)	176/177 (99%)	214/216 (99%)	139/162 (86%)	91/100 (91%)	236/235 (100%)	158/180 (88%)	0/104 (0%)	101/214 (47%)	
Test 11-19	122/122 (100%)	189/200 (95%)	36/124 (29%)	157/164 (96%)	223/228 (98%)	0/113 (0%)	151/158 (96%)	23/132 (17%)	85/164 (52%)		
Total (N=19)											66% (42%)
Jawbone Up Move											
Test 1-10	154/183 (84%)	69/151 (46%)	0/107 (0%)	0/182 (0%)	124/145 (21%)	0/146 (0%)	0/91 (0%)	0/69 (0%)	0/138 (0%)	0/199 (0%)	
Test 11-19	0/159 (0%)	0/172 (0%)	0/206 (0%)	129/178 (72%)	0/132 (0%)	50/207 (24%)	0/95 (0%)	0/185 (0%)	149/149 (100%)		
Total (N=19)											22% (35%)
ActivPAL3											
Test 1-10	194/199 (97%)	114/122 (93%)	24/159 (15%)	196/200 (98%)	146/172 (85%)	86/124 (69%)	202/206 (98%)	148/164 (90%)	178/178 (100%)	222/228 (97%)	
Test 11-17	112/132 (85%)	200/207 (97%)	140/158 (89%)	92/96 (96%)	84/132 (64%)	160/185 (86%)	130/149 (87%)				
Total (N=17)											85% (27%)

Appendix VII: Physical activity patterns of patients immediately after lumbar surgery (Chapter 6): Figures and Tables

Figure 1: Daily activity summary

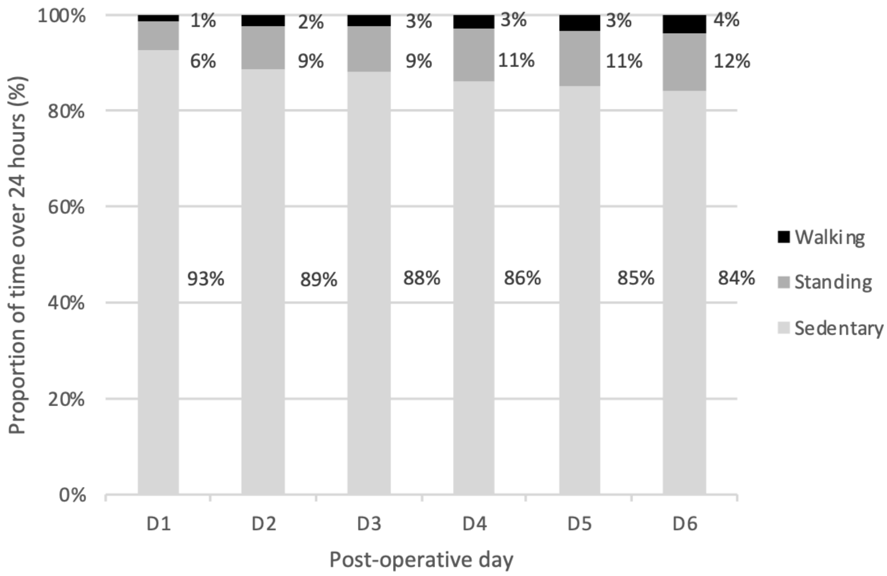


Figure 2: Mean step count – a) daily step count and b) hourly step count

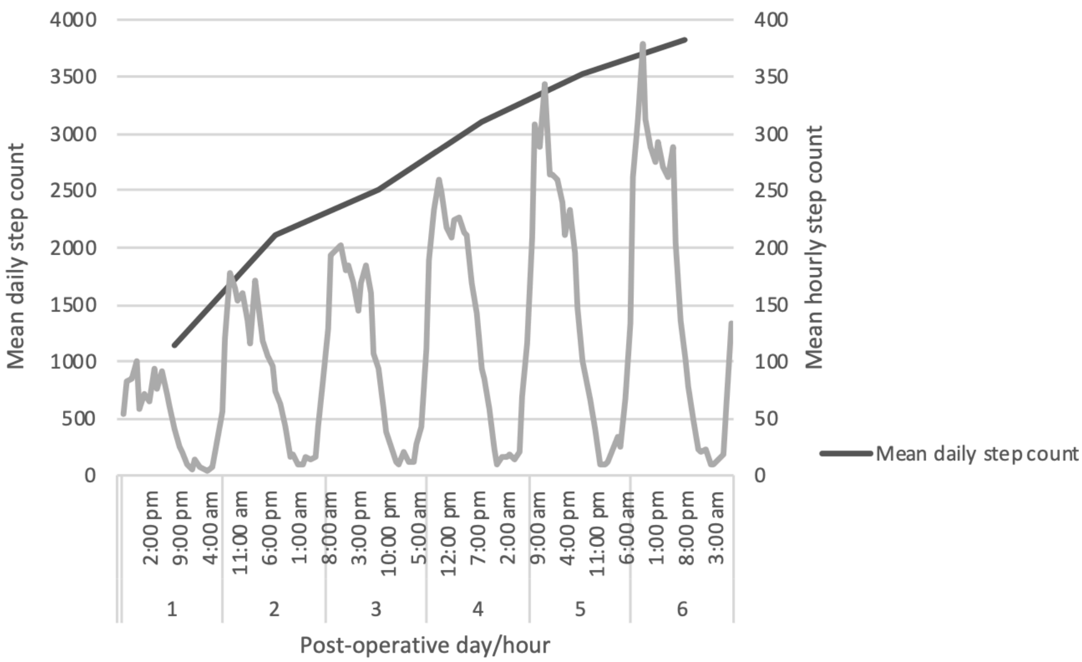


Table 1: Participant characteristics

			Incomplete data: N (%)
Age (years): mean (SD)	62	(13.9)	-
Sex			
Male: N (%)	105	(49%)	-
Female: N (%)		(51%)	-
Pre-operative characteristics:			
Duration of pain/symptoms (months): median (IRQ)	12	(4-36)	19 (9%)
Back pain (NPRS): mean (SD)	5.8	(2.8)	12 (6%)
Leg pain (NPRS): mean (SD)	5.9	(3.0)	12 (6%)
Physical function (ODQ): mean (SD)	44.4	(16.2)	11 (5%)
Physical function (SF-36 PCS): mean (SD)	33.2	(7.0)	16 (7%)
Physical activity (IPAQ-SF):			18 (8%)
High: N (%)	25	(12%)	
Moderate: N (%)	56	(26%)	
Low: N (%)	117	(54%)	
Mobility:			10 (5%)
Unrestricted (ODQ Section 4, <3): N (%)	102	(47%)	
Restricted (ODQ Section 4, ≥3): N (%)	104	(48%)	
Surgical procedure:			-
Lumbar decompression	58	(27%)	
Lumbar discectomy	89	(41%)	
Lumbar fusion	69	(32%)	
Single vertebral level	162	(75%)	
Multiple vertebral levels	51	(24%)	

Abbreviations: NRPS, Numerical Pain Rating Scale; ODQ, Oswestry Disability Questionnaire; SF-36 PCS, Short Form 36 Physical Component Summary; IPAQ-SF, International Physical Activity Questionnaire Short Form.

Table 2: Post-operative and discharge factors

			Incomplete data: N (%)
Post-operative complications (1st 7 days)			11 (5%)
Minor complications*: N (%)	55	(26%)	
Surgical complication (bed-rest): N (%)	5	(2%)	
Surgical complication (further surgery): N (%)	3	(1%)	
Day achieving independent mobility: median (IRQ)	2	(1-3)	11 (5%)
Discharge destination:			-
Home: N (%)	113	(52%)	
Rehabilitation: N (%)	103	(48%)	
Discharge day:			-
Total: median (IRQ)	4	(2.3-5)	
Discharge destination: home: median (IRQ)	3	(2-4)	
Discharge destination: rehab: median (IRQ)	5	(3-6)	

*Minor complications: nausea, vomiting, dizziness, hypotension, low haemoglobin requiring transfusion, infection (not at surgical site), cardiac arrhythmia, lethargy, confusion, migraine.

Table 3: Daily activity profile: summary of results

	Step count:		Walking time (mins):			Standing time (mins):			Sedentary time (mins):			Number of walking episodes greater than: 1 min:		5 min:		10 min:	
Post-op day	Mean	(SD)	Mean	(SD)	%	Mean	(SD)	%	Mean	(SD)	%	Mean	(SD)	Mean	(SD)	Mean	(SD)
1	1141.05	(1404.20)	17	(20)	1%	87	(83)	6%	1336	(97)	93%	3.73	(5.13)	0.20	(0.64)	0.08	(0.42)
2	2116.51	(2210.51)	31	(29)	2%	131	(100)	9%	1278	(122)	89%	7.03	(7.25)	0.70	(2.03)	0.26	(1.15)
3	2515.45	(2400.19)	36	(32)	3%	133	(88)	9%	1271	(114)	88%	7.50	(7.56)	0.81	(1.92)	0.42	(1.38)
4	3108.09	(2654.15)	44	(35)	3%	155	(95)	11%	1241	(122)	86%	9.23	(8.83)	1.14	(2.32)	0.65	(1.80)
5	3523.44	(2757.30)	48	(35)	3%	168	(99)	11%	1224	(125	85%	10.23	(9.54)	1.49	(2.58)	1.00	(2.28)
6	3823.37	(2949.86)	54	(38)	4%	174	(106)	12%	1212	(130)	84%	11.18	(9.14)	1.44	(2.47)	0.93	(1.99)
Total					3%			10%			88%						

Table 4: Association between total step count and pre and post-operative factors (continuous data)

	r	(95%CI)
Age	-0.35**	(-0.46 – -0.22)
Pre-operative factors:		
Duration of pain/symptoms	-0.30**	(-0.42 – -0.17)
Back pain severity (NRPS)	-0.21**	(-0.34 – -0.08)
Leg pain severity (NPRS)	-0.11	(-0.24 – 0.02)
Function (ODQ)	-0.06	(-0.19 – 0.07)
Function (SF36-PCS)	-0.11	(-0.03 – 0.24)
Post-operative factors:		
Back pain severity (NRPS)†	-0.27**	(-0.32 – -0.22)
Leg pain severity (NRPS)†	-0.12**	(-0.18 – -0.06)
Wound pain severity (NRPS)†	-0.20**	(-0.25 – -0.14)
Day achieving independent mobility	-0.60**	(-0.68 – -0.50)

**p*<0.05, ** *p*<0.01. †Correlation between step count and post-operative pain severity was calculated using daily step count and daily pain severity scores. Abbreviations: NRPS, Numerical Pain Rating Scale; ODQ, Oswestry Disability Questionnaire; SF-36 PCS, Short Form 36 Physical Component Summary.

Table 5: Association between step count and pre and post-operative factors (categorical data)

	Step Count (total) mean (SD)	Difference in mean step count between groups (95%CI)	*t*-statistic, *p*-value
Sex			
Male	17654 (13221)	3036 (-310 – 6382)	*t*=-1.79, *p*=0.08
Female	14618 (11716)		
Pre-operative factors:			
Pre-operative mobility			
Unrestricted (ODQ Section 4, <3)	17928 (13701)	3282 (-168 – 6732)	*t*=-1.88, *p*=0.06
Restricted (ODQ Section 4, ≥3)	14646 (11321)		
Pre-operative activity (IPAQ-SF)			
High	18644 (13239)	2801 (-2353 - 7955)†	*t*=1.07, *p*=0.29
Moderate	17212 (12408)		
Low	15188 (11893)	2465 (-1009 – 5939)§	*t*=-1.40, *p*=0.16
Surgical factors:			
Surgical Procedure			
Discectomy	21191 (12856)		
Decompression	14304 (9911)	6887 (2956 – 10818)¶	*t*=3.46, *p*=<0.01
Fusion	11024 (11733)	10167 (6245 – 14089)#	*t*=5.12, *p*<0.01
Number of vertebral levels			
Single	17701 (12822)	7015 (3159 – 10871)	*t*=3.59, *p*<0.01
Multiple	10686 (9845)		
Post-operative factors:			
Minor complications			
No	18519 (11847)	7505 (3823 – 11187)	*t*=4.02, *p*<0.01
Yes	11014 (11466)		
Surgical complications			
No	16613 (12189)	6056 (-2572 – 14665)	*t*=1.39, *p*=0.17
Yes	10557 (9218)		

†High compared to moderate/low; §Low compared to high/moderate; ¶Decompression compared to discectomy; #Fusion compared to discectomy. Abbreviations: IPAQ-SF, International Physical Activity Questionnaire Short Form.

Appendix VIII: Predictors of substantial improvement in physical function six months after lumbar surgery: is early post-operative walking important? A prospective cohort study (Chapter 7): Supplementary Tables

Table VII.1a: Characteristics of included and excluded participants (continuous data, independent *t*-tests)

	Included Mean (SD)	Excluded Mean (SD)	Difference in mean (95%CI)	*t*-statistic, *p*-value
Age (years)	61.59	60.64	0.96 (-3.25 – 5.17)	t=0.45, p=0.65
BMI	28.43	28.10	0.33 (-1.32 – 1.98)	t=0.40, p=0.69
Pre-operative pain duration (months)	40.80	30.82	9.98 (-12.94 – 32.90)	t=0.86, p=0.39
Pre-operative function (ODQ)	44.50	43.83	0.67 (-4.10 – 5.42)	t=-0.27, p=0.78
Pre-operative SF36 (PCS)	32.77	34.10	1.33 (-0.82 – 3.50)	t=-1.22, p=0.22
Pre-operative SF36 (MCS)	46.94	45.61	1.34 (-2.31 – 4.97)	t=0.72, p=0.47
Pre-operative back pain (NPRS, 0-10)	5.76	6.10	0.34 (-0.46 – 1.14)	t=-0.84, p=0.40
Pre-operative leg pain (NPRS (0-10)	5.77	6.27	0.50 (-0.40 – 1.40)	t=-1.10, p=0.27

BMI Body mass index, ODQ, Oswestry Disability Questionnaire;), SF36 Short Form 36, PCS Physical component Summary, MCS Mental Component Summary, NPRS Numerical Pain Rating Scale

Table VII.1b. Characteristics of included and excluded participants (dichotomous/categorical data, Chi Squared)

	Included: N (%)	Excluded: N (%)	Chi squared	*p*-value
Sex				
Male	83 (48%)	35 (57%)	1.50	*p*=0.22
Female	89 (52%)	26 (43%)		
Smoking Status				
Non-smoker	157 (91%)	57 (95%)	0.86	*p*=0.35
Smoker	15 (9%)	2 (5%)		
Diabetic				
No	155 (90%)	52 (87%)	0.55	*p*=0.46
Yes	17 (10%)	8 (13%)		
Depression				
No (PHQ-9 <10)	96 (57%)	34 (57%)	0.004	*p*=0.95
Yes (PHQ-9 ≥10)	72 (43%)	26 (43%)		
Anxiety				
No (GAD-7 <10)	117 (70%)	42 (70%)	0.003	*p*=0.96
Yes (GAD-7 ≥10)	51 (30%)	18 (30%)		
Neurological deficit (self-report)				
No	12 (7%)	5 (8%)	0.113	*p*=0.74
Yes	159 (93%)	55 (92%)		
Pre-operative activity (IPAQ-SF)				
Low	102 (61%)	28 (49%)	2.94	*p*=0.23
Moderate	43 (26%)	21 (37%)		
High	21 (13%)	8 (8%)		
Pre-operative mobility (ODQ Section 4)				
Un-restricted (<3)	84 (49%)	29 (48%)	0.03	*p*=0.86
Restricted (≥3)[a]	88 (51%)	32 (52%)		
Surgical procedure				
Decompression	44 (26%)	19 (32%)	2.98	*p*=0.23
Discectomy	68 (40%)	28 (46%)		
Fusion	60 (35%)	14 (23%)		
Number of vertebral levels				
Single	131 (76%)	44 (72%)	0.39	*p*=0.53
Multiple	41 (24%)	17 (28%)		

PHQ-9 Patient Health Questionnaire 9; GAD-7, Generalised Anxiety Disorder 7-item scale; IPAQ-SF, International Physical Activity Questionnaire Short Form; ODQ, Oswestry Disability Questionnaire; [a]Restricted mobility: ODQ Section 4, score of ≥ 3 (unable to walk more than 500m, or requires a stick, crutches or other support.

Table VII.2. Univariate analysis – correlation between predictor variables and achieving the SCB change threshold

	Function (ODQ)		Function[a] (SF-36 PCS)		Back Pain (NPRS)		Leg Pain (NPRS)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Total walking time (hours)	0.152*	0.048	0.196*	0.012	-0.062	0.421	0.059	0.450
Age <65years	0.065	0.358	0.195**	0.006	0.006	0.931	0.027	0.712
Sex (female)	0.156*	0.028	-0.016	0.830	0.107	0.133	0.145*	0.043
Smoker	-0.007	0.917	-0.048	0.509	0.052	0.468	0.051	0.475
Pre-operative obesity (BMI<30)	0.081	0.267	0.043	0.560	0.079	0.276	0.002	0.977
Pre-operative diabetes	0.055	0.438	-0.115	0.111	-0.010	0.893	0.028	0.694
Depression	0.057	0.425	-0.098	0.181	0.104	0.147	0.090	0.213
Anxiety	0.074	0.304	-0.138	0.058	0.057	0.430	-0.019	0.798
Pre-operative pain duration <12 months	0.238**	0.001	0.255**	0.000	-0.018	0.805	0.081	0.268
Pre-operative neurological deficit	0.044	0.542	0.025	0.729	0.078	0.277	0.043	0.550
Low pre-operative activity	0.190**	0.008	-0.034	0.647	0.019	0.797	0.055	0.454
Restricted pre-operative mobility[b]	0.296**	0.000	-0.029	0.690	0.093	0.191	0.058	0.418
Lower pre-operative function	0.447**	0.000	-0.040	0.581	0.075	0.293	0.140	0.050
Surgical procedure	-0.028	0.692	-0.059	0.412	-0.097	0.172	-0.093	0.193
Single-level surgery	0.119	0.093	0.026	0.716	0.055	0.441	0.127	0.075

*p<0.05; **p<0.01. Interpretation of results: Positive *r* values represent a greater chance of achieving the SCB threshold for each outcome when participants present with the listed characteristic, while negative *r* values represent a reduced chance of achieving the SCB threshold. SCB, Substantial Clinical Benefit; ODQ, Oswestry Disability Questionnaire; SF-36 (PCS), Short Form 36 Physical Component Summary; NRPS, Numerical Pain Rating Scale; BMI, Body mass index. [a]Quality of Life related to physical function; [b]Restricted pre-operative mobility: ODQ Section 4, score of ≥ 3 (unable to walk more than 500m, or requires a stick, crutches or other support)

Table VII.3a. Sensitivity analysis

3a: Linear regression analysis – change in outcome from pre-operative to six months post-operative

Outcome	Variable	β	(95%CI)	*p*
Function (ODQ)	Total walking time (hrs)	1.54	(0.60-2.48)	<0.01
	Pre-operative pain duration (months)	-0.04	(-0.07- -0.01)	<0.01
	Pre-operative function (ODQ, 0-100)	0.61	(0.46-0.77)	<0.01
Function (SF-36 PCS)	Age (years)[a]	0.16	(0.05-0.28)	<0.01
Back Pain (NPRS)	Restricted pre-operative mobility[b]	0.96	(0.06-1.86)	0.04
Leg Pain (NRPS)	Sex (Female)	1.13	(0.15-2.11)	0.03

Interpretation of results: For each unit increase of a predictor variable, β represents the concurrent change in OM score. For example, each additional hour walked would result in 1.54 points more improvement in the ODQ; participants with restricted pre-operative mobility would have a change in back pain of 0.96 points more on the NPRS than those with unrestricted mobility. ODQ, Oswestry Disability Questionnaire; SF-36 PCS, Short Form 36 Physical Component Summary; NRPS, Numerical Pain Rating Scale; [a]Negative change on the SF-36 (PCS) indicates improved function over time - improved function is associated with decreasing age; [b]Restricted mobility: ODQ Section 4, score of ≥ 3 (unable to walk more than 500m, or requires a stick, crutches or other support)

Table VII.3b. Logistic regression analysis (multiple imputation) – achievement of SCB threshold

Outcome measure	Variable	β	Exp (β)	(95%CI)
ODQ	Pre-operative Pain Duration <12months	1.00	2.71	(1.45-5.06)
	Pre-operative function (ODQ categories[a])	1.33	3.77	(2.52-5.87)
SF-36 (PCS)	Age <65	0.66	1.94	(1.02-3.68)
	Pre-operative Pain Duration <12months	0.90	2.46	(1.32-4.58)

Note: No significant predictive variables for change in back or leg pain. Interpretation of results: Exp (β) is equivalent to the odds ratio (OR). These variables may be applied to determine the odds of achieving the SCB threshold for the given outcome measure. For example, for a patient less than 65 years old, the odds of achieving the SF-36 (PCS) SCB is 1.94 greater than a patient 65 years or over. SCB, Substantial Clinical Benefit; ODQ, Oswestry Disability Questionnaire; SF-36 (PCS), Short Form 36 Physical Component Summary; [a]ODQ categories: 1: 0-20, 2: 21-40, 3: 41-59, 4: 60-79, 5: 80-100.

Table VII.3c. Linear regression analysis (multiple imputation) – change in outcome from pre-operative to six months post-operative

Outcome measure	Variable	β	(95%CI)	*p*
ODQ	Pre-operative pain duration (months)	-0.03	(-0.70- -0.10)	0.01
	Pre-operative function (ODQ, 0-100)	0.63	(0.49-0.76)	<0.01
	Single level surgery	-5.75	(-10.63—0.868)	0.02
SF-36 (PCS)	Age (years)[a]	0.14	(0.02-0.27)	0.03

Interpretation of results: For each unit increase of the predictor variable, β represents the concurrent change in OM score. For example, for each additional month of pre-operative pain the change in ODQ would decrease (negative association) by 0.03 points.

Note: No significant predictive variables for change in back or leg pain. ODQ, Oswestry Disability Questionnaire; SF-36 (PCS), Short Form 36 Physical Component Summary; [a]Negative change on the SF-36 (PCS) indicates improved function over time - improved function is associated with decreasing age.

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