Bond University

MASTER'S THESIS

Factors associated with early functional recovery following primary unilateral total hip and knee arthroplasty.

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Award date:
2021

Factors associated with early functional recovery following primary unilateral total hip and knee arthroplasty

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Submitted in total fulfilment of the requirements of the degree of
Master of Science by Research (Health Sciences)

July 2020

Faculty of Health Sciences and Medicine

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This research was supported by an Australian Government Research Training Program Scholarship.

ABSTRACT

The prevalence of osteoarthritis is growing in many countries including Australia, and accounts for the vast majority of primary total hip arthroplasty (THA) and total knee arthroplasty (TKA) surgeries performed. In Australia, demand for these elective procedures has increased substantially over the last 15 years, adding further burden to healthcare costs and resources. Hence, efficient delivery of quality patient care is paramount to accelerate early post-operative recovery and reduce the length of hospital stay and, ultimately, the costs associated with these surgeries. To this end some healthcare organisations have implemented Enhanced Recovery Pathways (ERP) whereby each step of the patient surgical journey has been rationalised and optimised.

The introduction of ERP for THA and TKA has demonstrated both patient and organisational benefits. However, ERP are complex in nature and comprise multiple components for which there are currently no standardised guidelines. Thus, ERP vary between healthcare organisations, as do their measures of success, particularly inpatient functional outcomes. Despite inpatient functional recovery being essential for safe and timely hospital discharge following THA and TKA, research undertaken to establish prognostic factors for inpatient functional recovery is limited, and therefore forms the topic of this thesis.

An initial literature review (Chapter 2) identified only a single systematic review which investigated patient-related predictors of inpatient recovery and length of stay (LOS) following THA. Thus, evidence regarding associations between individual surgical factors and inpatient recovery, which could inform ERP, had not been considered. Importantly, there is currently no gold standard tool by which to assess inpatient functional recovery.

A systematic review (Chapter 3) was therefore conducted to examine the available evidence for both patient and surgical factors associated with early post-operative function (assessed using validated measures) following THA and TKA. Strong level evidence supported pre-operative Timed Up and Go time and American Society of Anesthesiologists grade as factors significantly associated with inpatient functional recovery following TKA. However, studies of early functional recovery were found to be heterogenous in nature. Variance in methodological quality, variables examined, outcome measures, and the time points at which they were assessed, impeded synthesis of results. Furthermore, recent surgical

advances including muscle-sparing approaches and robot-assisted surgery had not been assessed.

A prospective cohort study (Chapter 4) was undertaken to explore the potential prognostic relationship between patient and surgical factors and inpatient functional recovery following THA and TKA. Secondary outcome measures were acute hospital LOS, and longer-term patient-reported functional outcomes assessed at six months post-operatively. Inpatient functional recovery was assessed on the afternoon of the second post-operative day using objective performance measures relevant to the early post-operative time points and reflective of the tasks required for safe discharge from acute orthopaedic wards. Patient-related factors significantly prognostic for inpatient functional recovery in the study population included age, sex, pre-operative function, general health, and Risk Assessment and Prediction Tool score. Significant surgical prognostic factors in the study population included techniques for administering analgesia and anaesthesia, arthroplasty site, and surgical approach (for THA).

This program of research has demonstrated that several patient-related factors assessed pre-operatively, as well as surgical and post-operative factors were associated with inpatient functional outcomes, and with LOS in patients following THA and TKA. In addition, longer-term functional outcomes for these patients reflected their inpatient functional outcomes. Standardised functional outcome measures are needed to evaluate patient-centred ERP outcomes, and to facilitate benchmarking, auditing and improving ERP.

KEY WORDS

total hip arthroplasty
total knee arthroplasty
total hip replacement
total knee replacement
predictors
prognostic factors
functional recovery
inpatient recovery

DECLARATION BY AUTHOR

This thesis is submitted to Bond University in fulfilment of the requirements of the degree of Master of Science by Research (Health Sciences).

This thesis represents my own original work towards this research degree and contains no material that has previously been submitted for a degree or diploma at this University or any other institution, except where due acknowledgement is made.

Nicola Ann Hewlett-Smith

Signature:
Date: 21.07.2020

DECLARATION OF CO-AUTHORS

The authors listed below have all approved inclusion and publication of the manuscripts contained within this thesis. Relative contributions are provided for each study manuscript.

Publication co-authored	Statement of contribution
Hewlett-Smith N, Pope R, Furness J, Simas V, Hing W. *Prognostic factors for inpatient functional recovery following total hip and knee arthroplasty: a systematic review.* Acta Orthopaedica 2020; 91. DOI: 10.1080/17453674.2020.1744852 (Appendix I)	**NH-S 70%**, RP10%, JF 10%, VS 5%, WH 5%
Hewlett-Smith N, Pope R, Hing W, Simas V, Furness J. *Patient and surgical prognostic factors for inpatient functional recovery following THA and TKA: a prospective cohort study.* Journal of Orthopaedic Surgery and Research (2020) 15:360. https://doi.org/10.1186/s13018-020-01854-9 (Appendix V)	**NH-S 75%**, RP 15%, WH 5%, VS 3%, JF 2%

RESEARCH OUTPUTS

Peer-reviewed publications

Hewlett-Smith N, Pope R, Furness J, Simas V, Hing W. *Prognostic factors for inpatient functional recovery following total hip and knee arthroplasty: a systematic review.* Acta Orthopaedica 2020; 91. DOI: 10.1080/17453674.2020.1744852
(Appendix I)

Hewlett-Smith N, Pope R, Hing W, Simas V, Furness J. *Patient and surgical prognostic factors for inpatient functional recovery following THA and TKA: a prospective cohort study.* Journal of Orthopaedic Surgery and Research (2020) 15:360.
https://doi.org/10.1186/s13018-020-01854-9
(Appendix V)

ETHICS DECLARATION

The research associated with this thesis involved human subjects and was carried out at The Wesley Hospital, Brisbane. Ethics approval was sought and received from the Uniting Care Human Research Ethics Committee (UCHREC), ethics application number 2016.09.187, and the Bond University Human Research Ethics Committee (BUHREC), ethics application number 15685.

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Chapter 3: Systematic Review

Hewlett-Smith N, Pope R, Furness J, Simas V, Hing W. Prognostic factors for inpatient functional recovery following total hip and knee arthroplasty: a systematic review. *Acta Orthopaedica* 2020; 91. DOI: 10.1080/17453674.2020.1744852

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Chapter 4: Prospective Cohort Study

Hewlett-Smith N, Pope R, Hing W, Simas V, Furness J. *Patient and surgical prognostic factors for inpatient functional recovery following THA and TKA: a prospective cohort study.* Journal of Orthopaedic Surgery and Research (2020) 15:360. https://doi.org/10.1186/s13018-020-01854-9

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Appendix VIII: modified Iowa Level of Assistance Scale

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Appendix IX: EQ-5D English (UK) sample version

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ACKNOWLEDGEMENTS

The journey culminating in completion of this thesis has been a tremendous challenge, of which I am very proud, if not a little astonished that I have managed to accomplish. This experience has afforded me the opportunity to not only broaden my skills and knowledge but also to learn an enormous amount about myself. To all who have contributed to this thesis or supported me along this journey, I wish to express my sincere thanks and appreciation.

Firstly, the completion of this thesis would not have been achievable without the guidance and support provided by my supervisory team. I am indebted to each of you, but in particular, to Professor Rod Pope. Your availability, calm and positive manner, and unfailingly constructive feedback boosted my spirits and encouraged me every step of the way. My primary supervisor, Professor Wayne Hing, challenged me to reach deeper and strive harder. Your praise was always more hard-won and thus that much sweeter when received. Associate Professor James Furness, your valuable suggestions provided additional perspective and enhanced various stages of my research. Finally, Dr Vini Simas, your patient mentorship was invaluable.

Also at Bond, I wish to acknowledge Evelyn Rathbone, for your kindness, generosity of time, and statistical expertise; and David Honeyman for your assistance in developing my systematic review search strategy. To my fellow Bond candidates, Ross Ferguson and Jen Phillips, your kinship, support, and understanding along this epic journey have been truly valued.

At The Wesley Hospital, firstly, my sincere thanks to all study participants- without you this research would not have been possible. I also wish to acknowledge the in-kind support provided by The Wesley Hospital which provided access to both patients and records, and allowance of staff time to enable data collection. In addition, my heartfelt thanks to so many Wesley Hospital staff. To Lisa Haigh (Head of Profession- Physiotherapy), and all those in the Physiotherapy Department who dutifully performed outcome measures, especially Alex Janovsky whose oversight of the data collection phase in my absence was invaluable, and for which I am exceedingly grateful. Also to the staff in Pre-admission Clinic, and orthopaedic wards MB1 and 1M, in particular Emily Dunn, Michelle Eacott, Dr Kate Brunello, Dr Rohan Brunello, and Dr Bjorn Smith I am grateful for your interest, support, and generous contributions throughout various stages of my research.

To my family. Simon- you have kept me going. Without your faith, patience, and unwavering support - this would not have been possible. To my boys, Harry and Oliver, so small when I started and now young men. For your understanding of my endless hours spent in the study, and willingness to assist however possible (even offering yourselves as potential study candidates)- I am forever thankful. I look forward to spending more time with you. To my parents, who have, without doubt, shaped me into the person I am today. The dedication, perseverance, and conscientiousness which drive my work ethic, I attribute to you both.

Finally, this program of research was supported by an Australian Government Research Training Program Scholarship. The prospective cohort study (Chapter 4) was registered with the EuroQol Research Foundation (Registration number 24351). Permission was sought and granted by the EuroQol Research Foundation for use of the English (Australia) EQ-5D-5L Self complete- Paper version to assess the pre-operative and post-operative general health of the participant cohort studied as part of this program of research. The EQ-5D-5L was used in accordance with the User Guide available at https://euroqol.org/publications/user-guides/. In addition, licenses were sought and granted by Oxford University Innovation for use of the English (Australia) versions of the Oxford Hip Score (OHS) and Oxford Knee Score (OKS) during the prospective cohort study (Chapter 4). The OHS and OKS assessed pre-operative and post-operative functional outcomes of the participant cohort and were implemented according to the relevant User Manuals, purchased through Oxford University Innovation.

Nicola Hewlett-Smith

"Accept the challenges so that you can feel the exhilaration of victory"

George S. Patton (1885-1945)

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LIST OF ABBREVIATIONS

activities of daily living	ADL
American Knee Society Score	AKSS
American Society of Anaesthesiologists	ASA
area under the curve	AUC
body mass index	BMI
coronary artery disease	CAD
Critical Appraisal Skills Programme	CASP
case control study	CCS
Community Health Activities Model Program for Seniors	CHAMPS
confidence interval	CI
direct anterior approach	DAA
de Morton Mobility Index	DEMMI
day of surgery admission	DOSA
direct superior approach	DSA
extended care facility	ECF
Enhanced Recovery Pathway	ERP
EuroQol-5 Dimension	EQ-5D
femoral nerve block	FNB
Fast-Track	FT
haemaglobin	Hb
hand grip strength	HGS
Hip Disability and Osteoarthritis Outcome Score	HOOS
International Classification of Function, Disability and Health	ICF
Iowa Level of Assistance Scale	ILAS
inter-quartile range	IQR
Identification of Seniors At Risk	ISAR
Knee injury and Osteoarthritis Outcome Score	KOOS
Lower Extremity Functional Scale	LEFS

local infiltration analgesia	LIA
length of stay	LOS
Modified Barthel Index	MBI
modified Iowa Level of Assistance Scale	mILAS
Mini-Mental State Examination	MMSE
not reported	NR
Numerical Rating Scale	NRS
not significant	*ns*
osteoarthritis	OA
Osteoarthritis American Resources and Services	OARS
Osteoarthritis Research Society International	OARSI
Oxford Hip Score	OHS
Oxford Knee Score	OKS
occupational therapist	OT
posterior approach	PA
Post Anaesthetic Care Unit	PACU
Psychogeriatric Assessment Scales	PAS
patient-controlled analgesia	PCA
preferred reporting items for systematic reviews	PRISMA
prospective cohort study	PCS
post-operative day	POD
Profile of Mood States	POMS
Prospectively Registered Systematic Reviews in Health and Social Care	PROSPERO
Post-operative Quality of Recovery Scale	PQRS
patient-reported outcome measure	PROM
physiotherapist	PT
quality of life	QOL
randomised controlled trial	RCT
Readiness for Hospital Discharge Scale	RHDS
routine incision	RI
regular protocol	RP
range of motion	ROM

Ropivacaine	Ropiv
Stair Climbing Test	SCT
standard deviation	SD
Short Form-12	SF-12
small incision	SI
total hip arthroplasty	THA
total knee arthroplasty	TKA
Timed Up and Go	TUG
United Kingdom	UK
unicompartmental knee arthroplasty	UKA
Visual Analogue Scale	VAS
Western Ontario and McMaster Universities Osteoarthritis Index	WOMAC
World Health Organization	WHO
2 Minute Walk Test	2MWT
6 Minute Walk Test	6MWT
10 metre Walk Test	10mWT
25 metre Walk Test	25mWT

CHAPTER 1: INTRODUCTION

Osteoarthritis

Osteoarthritis (OA) is a chronic, degenerative disease charaterised by the deterioration of joint (articular) cartilage causing pain, stiffness, and impaired movement (1). Worldwide, OA is one of the most common causes of disability in older adults (2), with associated pain, physical limitations and depression impacting social, community and occupational engagement (3). OA affects 21% of Australians over the age of 45 years, and prevalence increases markedly to 36% in those aged 75 years and older (4).

Risk factors for OA include ageing, excess weight, genetic predisposition, female sex, trauma and repetitive joint loading through activities such as kneeling, squatting and lifting (4). The prevalence of OA in Australia and many other countries is increasing due to population ageing and an increase in other risk factors such as inactivity, and obesity (4). Whilst certain factors such as exercise, diet and occupational hazards can be addressed; age, sex and genetics are not modifiable (4). Pharmacological methods may provide symptomatic relief, however definitive management of OA is commonly via joint replacement surgery (arthroplasty), whereby the damaged joint is removed and replaced with a prosthetic joint (4).

OA is the predominant condition leading to hip and knee arthroplasty in Australia and accounts for 88.6% of primary total hip arthroplasty (THA) and 97.7% of primary total knee arthroplasty (TKA) procedures (5). The number of primary THA and TKA procedures has risen steadily over the last two decades in Australia and other developed countries (6). Since the inception of the Australian National Joint Replacement Registry in 2003, there has been a reported 108% increase in primary THA and 156% increase in primary TKA procedures (5). Based on growth over the ten year period 2003 to 2013, the incidence of primary THA and TKA in Australia in 2030 is predicted to be 79 795 and 161 231 procedures respectively (6). The increasing burden of elective procedures such as THA and TKA has significant implications for health care costs and resources (6).

Enhanced Recovery Pathways

Orthopaedic surgery, including THA and TKA, accounts for one of the greatest hospital expenditures (7), thus the global impact of OA poses a considerable challenge for healthcare organisations, worldwide (8). Due to the increasing demands on healthcare organisations, efficient provision of quality patient care is paramount in order to service patient needs whilst sustainably managing resources and healthcare costs. Conceived in Denmark in the 1990s, the concept of Enhanced Recovery was initially applied to colorectal surgery and has subsequently gained recognition as an effective, efficient means of healthcare delivery for many surgical procedures, including THA and TKA (9-16).

Enhanced Recovery is an evidence based, multimodal approach to patient care, which aims to prepare patients for surgery, reduce the negative impact of surgery, and optimise the patient's ability to achieve a more rapid recovery (17). The first step in adopting an Enhanced Recovery approach involves the examination, rationalisation and optimisation of every step, pre-operative to post-operative, of the patient's surgical journey (11,13). These processes facilitate the generation of a streamlined care pathway combining evidence-based clinical features with optimal organisational efficiency (11,13). Such pathways are described in the literature under various terms such as Enhanced Recovery Pathways, Fast-Track, Enhanced Recovery After Surgery, and Care Pathways. In this document, they will collectively be referred to as Enhanced Recovery Pathways (ERP).

ERP have been implemented within several countries with considerable benefit demonstrated to both patients and healthcare organisations. Patient benefits include reduced post-operative morbidity (13,14,16) and mortality (14), earlier achievement of functional milestones and discharge criteria (13,14), without compromising patient satisfaction (9,11,19), quality of life (19) or re-admission rates (13,14,16). Healthcare organisations benefit through economic savings associated with reductions in overall hospital costs and reduced length of stay (LOS) (10,11,13,14,16,20).

The ERAS (Enhanced Recovery After Surgery) Society® have identified approximately 20 components of patient care that influence the body's response to surgery and enhance recovery (18). Thus, ERP are complex in nature and their implementation requires a collaborative multidisciplinary approach (11,14,18). As such, ERP should involve expertise from surgical, anaesthesiology, nursing and allied health disciplines (18). Components of ERP have been broadly categorised into clinical features (pertaining to the patient) and organisational features. Common features of ERP suggested for THA and TKA populations are presented in Table 1.

Table 1: Summary of clinical and organisational features of ERP for THA and TKA (9,11,13-15,18,20-23).

Clinical features	Organisational features
• Pre-operative optimisation including correction of anaemia, malnutrition screening, promotion of alcohol and smoking cessation • Reduced fasting times • Carbohydrate loading protocols • Pre-emptive analgesia • Regional anaesthesia • Multimodal opioid-sparing analgesia • Use of Tranexamic acid to minimise peri-operative blood loss • Standardised protocols for peri-operative fluid management, transfusion, antimicrobial prophylaxis, venous thromboembolic prophylaxis and management of post-operative nausea and vomiting • Minimal use of drains and catheters • Rapid resumption of eating and drinking • Day of surgery mobilisation	• Standardised care pathway • Multidisciplinary pre-admission consultation incorporating patient education, planned length of stay, discharge planning • Dedicated arthroplasty unit with consistent dedicated staff • Day of surgery admission • Functional discharge criteria

Early mobilisation has been deemed a key clinical feature of ERP (11,13,15,22) as its achievement facilitates functional recovery, reduces the risk of post-operative complications associated with prolonged bedrest (13), and is dependent on the appropriate management of many peri- and post-operative aspects of the pathway (16). Successful mobilisation in the early post-operative period requires a low incidence or effective management of post-operative anaemia, dizziness, nausea or vomiting; timely return of muscle power and sensation; adequate analgesia; available staff; and ideally, minimal attachments such as drains and catheters (11,13,15,16). Hence, early mobilisation and subsequent functional recovery may be strong clinical indicators of successful ERP.

Integral organisational features of ERP for lower limb arthroplasty include multi-disciplinary Pre-admission Clinics, dedicated specialised orthopaedic staff, and importantly, the rationalisation and standardisation of all aspects of the pathway (11,13). Pre-admission

Clinics impart patient information, enable pre-operative medical optimisation, and commence early discharge planning. Pre-operative education is necessary to align patient expectations, motivate the patient to be an active participant in their post-operative recovery, and provide information regarding the intended LOS (13). To ensure relevance to a particular healthcare service and its local population ERP may vary. However, the standardisation of processes and procedures comprising an ERP reportedly achieves the greatest organisational gains (11,13,16) due to the provision of consistent care and information, the ability to maximise organisational efficiency, and reasonably predict patient outcomes (13).

Although particular components of ERP have been identified in the literature, there are no standardised guidelines that apply to each of these components which would more readily facilitate implementation (24). The lack of defined guidelines, and the numerous components that ERP contain means that successful implementation requires strong clinical and managerial leadership, and multidisciplinary consensus at an organisational level (24). The consensus needed to enable a standardised approach for each ERP component may prove challenging in many healthcare facilities (due to the autonomy of multiple clincal service providers). Recent reviews of ERP literature have suggested that future research should focus on understanding which components of the pathway contribute to improved recovery (18), and quantifying the impact of individual variables (23). An understanding of which factors are most associated with early post-operative functional recovery may direct attention to particular components of the pathway, thus further improving ERP outcomes, in particular patient-related outcomes.

Traditionally, ERP outcomes have been determined via the incidence of post-operative patient morbidity and mortality, re-admission rates, LOS, patient satisfaction and organisational economic savings (13). LOS is commonly used as a primary outcome measure in the acute setting, however, it is thought to be subject to many factors other than patients' actual physical function and therefore may not accurately reflect the success of ERP interventions. Moreover, LOS may be pertinent to organisational efficiency, however, it holds little direct relevance to the patient**.** With patient-centred care a strong focus in healthcare, early functional recovery may be a more valuable outcome measure for ERP interventions, indicative of both clinical and organisational components, and relevant to both the patient and the healthcare organisation (20).

Functional Recovery

Through the International Classification of Function, Disability and Health, the World Health Organization describes a relationship between function, activity and participation (25). See Figure 1.

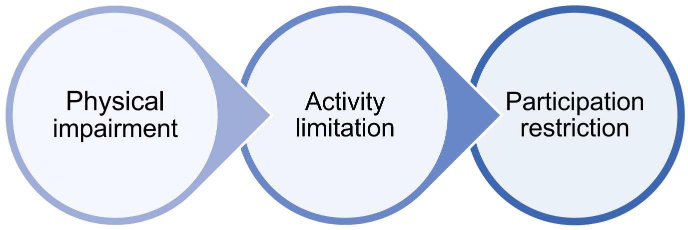

Figure 1: Relationship between function, activity and participation; adapted from the International Classification of Function, Disability and Health (25)

The pattern of recovery following lower limb arthroplasty has been analysed in relation to this framework (26). Importantly, change in one component influences the status of another component, for example, a reduction in physical impairment is associated with less activity limitation and this in turn, is associated with less restricted participation (26). On this basis, recovery of movement-related function is significantly linked to quality of life (QOL) by determining an individual's capability to perform various tasks, establish and maintain relationships and participate as desired within the community (25).

Functional recovery involves the regaining of movement necessary to perform essential activities of daily living (ADL) such as walking, getting in and out of bed and climbing stairs (27). Inability to perform basic ADL following surgery may increase an individual's risk of social isolation and falls, or the need for additional resources such as rehabilitation and community services (27). From a physiotherapy perspective, adequate functional recovery is a primary factor when considering patient safety and readiness to discharge from the acute hospital setting (27,28).

Formal discharge criteria which assess the patient's ability to safely and independently perform basic ADL may assist in reducing hospital LOS (9) and re-admissions secondary to acopia (13). Based on clinical experience, the presence of formal discharge criteria may also serve to support clinicians' recommendations regarding readiness to discharge, particularly when faced with "power" issues such as bed availability and pressure to disharge patients. Function-based discharge criteria have been used in some studies to assess readiness for discharge following THA and TKA (9,10,12,22,29,30), however, these criteria are heterogeneous and no evidence could be found by this author to confirm their validity.

Arthroplasty surgery is primarily sought to reduce pain and stiffness associated with OA, thus enabling improvement in physical function and QOL (31). Improvements in functional mobility and decreased pain have been cited as the most important pre-operative expectations of surgical outcome in patients undergoing both THA and TKA (32). Expectation fulfilment has been demonstrated to correlate closely with post-operative satisfaction (32) and patient-reported functional outcome following THA (33) and TKA (34). Functional recovery is necessary to fulfil these expectations. Therefore, early post-operative functional recovery is of great importance to patient outcomes through its association with fulfilment of surgical expectations, longer-term outcomes, and overall post-operative satisfaction.

Inpatient functional recovery is also relevant to the healthcare organisation through its links to post-operative morbidity and its impacts on discharge readiness, LOS (9,10,13,20), and satisfaction with hospital experience (35). It is well documented that economic costs associated with lower limb arthroplasty are significantly influenced by LOS. Therefore rapid post-operative recovery of function necessary for discharge is fundamental to avoiding the costs associated with prolonged LOS.

Pain has been cited as the second most common predictor of reduced satisfaction with hospital experience in patients following TKA (35). As post-operative pain can significantly impact early functional recovery (13,20), functional recovery may then also be linked to hospital experience. Satisfaction with hospital stay has been reported as an independent predictor of patient-reported outcome and overall satisfaction following TKA (35). THA and TKA are commonly undertaken as elective procedures, therefore consumer satisfaction with hospital stay, and ultimately surgical outcome should be key considerations for healthcare organisations. However, relatively few studies have focused on early functional recovery as a primary measure and research on predicting early functional recovery has been limited (36).

Significance

The significance of creating a prognostic model for inpatient functional recovery following THA and TKA is twofold. Firstly, the identification of pre-operative patient-related factors associated with increased risk of delayed functional recovery and potentially prolonged hospitalisation may guide pre-operative patient preparation through both functional and medical optimisation, and early, focused discharge planning (30). Secondly, the identification of key surgical, patient-related factors influencing post-operative functional recovery may potentially inform the refinement of peri- and post-operative aspects of ERP. This may be particularly useful in organisations where the standardisation of processes proves more challenging. Prognostic models of these types, once validated, may enhance patient-centred care and optimise outcomes, particularly functional outcomes, for patients undergoing THA and TKA (37). In addition, they may also benefit organisational efficiency by facilitating the prediction of inpatient flow.

Aims

The overall aim of the research reported in this thesis was to assess the strengths of associations between a comprehensive set of potential prognostic factors including patient-related and surgical variables and objectively measured inpatient functional recovery (assessed on post-operative day 2) in patients following a partially-standardised ERP for primary, unilateral THA and TKA in a private hospital setting.

The overarching research question was as follows:
What are the relationships between patient-related and surgical factors, and inpatient functional recovery (assessed on post-operative day 2) in patients following a partially-standardised ERP for primary, unilateral THA and TKA in a private hospital setting.

The specific objectives of the program of research were:

- To analyse the relationships between patient-related and surgical factors, and functional recovery on post-operative day 2 in patients following a partially-standardised ERP for primary, unilateral THA and TKA in a private hospital setting, and based on these findings, create prognostic models for functional recovery on post-operative day 2 for the studied population;

- To analyse the relationships between patient-related and surgical factors and hospital LOS in patients following a partially-standardised ERP for primary, unilateral THA and TKA in a private hospital setting;

- To assess the relationship between objectively measured inpatient function and patient-reported functional outcomes assessed at six months post-operatively in patients following a partially standardised ERP for primary, unilateral THA and TKA in a private hospital setting.

Hypotheses

Key research hypotheses were as follows:

- An association exists between both patient-related and surgical variables and functional performance outcomes during the inpatient period, in patients following a partially-standardised ERP for primary, unilateral THA and TKA in a private hospital setting, however, these variables may differ between arthroplasty types;

- An association exists between both patient-related and surgical variables and hospital LOS in patients following a partially-standardised ERP for primary, unilateral THA and TKA in a private hospital setting, however, these variables may differ between arthroplasty types;

- An association exists between objectively measured inpatient function and patient-reported functional outcomes assessed at six months post-operatively in patients following a partially-standardised ERP for primary, unilateral THA and TKA in a private hospital setting.

Program of research

The focus of this program of research was on validated measures of inpatient functional recovery, and the three key components of the research were as follows:

1. *A narrative literature review* first explored the factors identified in previous studies to be associated with functional outcomes and hospital LOS following THA and TKA.

2. *A systematic review* was then conducted to identify, critically appraise and synthesise key findings from published studies that have specifically investigated factors which may be prognostic indicators of early post-operative functional recovery in the THA and TKA patient population. Gaps in the literature identified through this systematic review informed the subsequent prospective cohort study in this program of research.

3. *A prospective cohort study* constituted the primary study in this program of research. The aim of this study was to examine the strengths and forms of associations between a range of potential prognostic factors for post-operative functional recovery (including patient-related and surgical variables) and objectively-measured post-operative functional recovery, during the inpatient hospital stay in patients following a partially-standardised ERP in a private hospital setting. Hospital LOS along with patient-reported functional outcomes at six months post-operatively were also assessed, as secondary outcome measures, so that relationships between inpatient function, LOS and longer-term functional outcomes could be assessed. Finally, those prognostic factors that were found individually to be significantly associated with inpatient functional outcomes in the study population were entered into multiple regression analyses to derive prognostic models for further validation in new patient cohorts.

CHAPTER 2: NARRATIVE LITERATURE REVIEW

Preface

Literature relating to Enhanced Recovery Pathways (ERP) indicates that factors influencing post-operative patient outcomes can be broadly categorised as relating to the individual patient, their surgical management, or aspects of the healthcare organisation (13). Although ERP outcomes may not be routinely assessed in terms of patient function, many of the factors affecting ERP outcomes are also likely to impact early post-operative recovery, following total hip arthroplasty (THA) and total knee arthroplasty (TKA). Thus, as discussed in Chapter 1, early post-operative functional recovery may be considered a valid indicator of the success of ERP interventions. This chapter will broadly review the literature pertaining to factors associated with early functional recovery and hospital length of stay (LOS) following THA and TKA. Valid methods of evaluating functional outcomes in this patient population will also be considered, as these are critical to examining the relationships between potential prognostic factors and functional outcomes.

Assessing Functional Recovery

Determining the patient's functional ability following surgery necessitates a valid outcome measure (38). However, valid tools to assess short-term post-operative function following lower limb arthroplasty are lacking (38,39) and currently there is no gold standard for assessing functional recovery in acute hospital inpatients (39). Consequently, there is little consistency in the methods used to evaluate early post-operative functional recovery (37). Function-based discharge criteria have been used to assess inpatient functional recovery and determine discharge readiness in several studies (9,10,12,21,22,29,30), however, these criteria are neither validated nor standardised, hence limiting the comparison of study findings. Before discussing factors associated with functional recovery following THA and TKA in the following section, it is important to consider how functional recovery can be measured.

There are several valid outcome measures for assessing longer-term function following THA and TKA. These include the Lower-Extremity Functional Scale (LEFS), Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC), Hip Disability and Osteoarthritis Outcome Score (HOOS)/ Knee Injury and Osteoarthritis Outcome Score (KOOS), Oxford Hip Score (OHS) and Oxford Knee Score (OKS) (40). However, these outcome measures assess more advanced functional activities, such as squatting, kneeling, jumping, running and heavy domestic duties (38), which are not achieved within the acute recovery phase and do not reflect simple activities of daily living (ADL) patients need to be able to perform prior to hospital discharge.

There are two broad categories of tools used to assess function: patient-reported outcome measures (PROMs) and performance outcome measures (27). PROMs involve the patient self-reporting their perceived function via questionnaires, whereas performance measures score the patient's observed capacity to complete one or more functional tasks (38). Patient perceptions of function in the early post-operative period may be influenced positively or negatively by multiple factors including pain or perceived level of exertion when performing tasks (41), nausea, level of alertness (38), anxiety associated with hospitalisation, coping ability or expectations regarding recovery (42). Only low to moderate correlations have been reported between PROMs and performance measures in the early post-operative period following both THA and TKA (38,41,43). On this basis, performance-based tests are necessary to objectively assess functional recovery in the early post-operative period after

THA and TKA, as they provide objective information including restrictions associated with muscle weakness or range of motion that may not be captured by PROMs (41,44). A valid functional performance measure, appropriate to the time point at which it is implemented, would assist in objectively assessing functional recovery and discharge readiness following THA and TKA; and aid in evaluating the effectiveness of Enhanced Recovery interventions implemented with the purpose of reducing post-operative morbidity and facilitating early post-operative functional recovery (38). Examples of outcome measures appropriate for this purpose, in this patient population, include the Iowa Level of Assistance Scale (28) and the modified Iowa Level of Assistance Scale (45) which each assess tasks including bed and chair transfers, ambulation, stair climbing, and the amount of assistance required for their achievement.

Factors associated with early and inpatient functional recovery following THA and TKA

Inpatient functional recovery is reflective of post-operative morbidity (13), closely linked to discharge destination, and may impact quality of life (31), patient satisfaction (32), LOS, and associated healthcare costs (9,10,20). However, the rate of inpatient post-operative recovery, is variable and unpredictable (37), and, as noted in previous sections, research on predicting early functional recovery within the usual hospital inpatient period of less than ten days is limited (36,37).

To determine individual factors that may be associated with early and inpatient functional recovery following THA and TKA a narrative review was undertaken. The PubMed database was searched for literature which included the keywords “predict”, “function” and “arthroplasty” within title or abstract. The wildcard function was also employed for each keyword. All studies that assessed the potential prognostic relationship between patient-related or surgical factors, and either PROMs or performance based outcome measures within two weeks of primary, unilateral THA or TKA procedures were reviewed.

At the time this narrative review was undertaken, there appeared to be only one systematic review that examined potential predictors of inpatient functional recovery following either THA or TKA. That systematic review (37), examined the predictive relationship between pre-operative patient-related factors and inpatient functional recovery or LOS after elective primary THA. During that systematic review (37), publications up to April 2014 were screened, and fourteen studies of English or Dutch language met inclusion criteria. One Chinese study was excluded as translation was not possible. However, of the fourteen included studies, only two studies examined predictors of inpatient functional recovery (46,47). A best evidence synthesis approach determined that no potential predictors examined were found to have a strong level of evidence to support them (37). For the associations between inpatient functional recovery (of greater than four days) and female sex (ß -34.45; 95% confidence interval -65.70, -3.20), higher body mass index (BMI) (ß -2.61; 95% confidence interval -5.18, -0.03), and less pre-operative independence with ADL (OR 6.00; 95% confidence interval 1.30, 28.3); a moderate level of evidence was reported. There was conflicting evidence for an association between slower inpatient functional recovery and higher age. However, aside from age, the two included studies that considered functional recovery as an outcome did not examine the same patient-related predictor variables; nor was the same outcome measure used to assess inpatient functional recovery. Sufficient detail of surgical protocols, post-operative pain management and physiotherapy intervention was reported by only one of the studies (47). These limitations impact the generalisability of the systematic review findings.

The narrative review identified several other studies which had examined potential prognostic factors for early post-operative functional recovery that were not included in the systematic review conducted by Elings et al (37). These additional studies were published subsequent to the cut-off date of April 2014 of the aforementioned systematic review (37), or did not meet the inclusion criteria of the aforementioned systematic review (37) ie: examined potential prognostic factors for post-operative functional recovery following TKA. A summary of the findings of these additional studies is presented in Table 2.

Table 2: Factors associated with early functional recovery following total hip and knee arthroplasty

Author Year of publication	Country, number of sites, hospital funding	Surgery type	Population n=	Factor type	Individual potential prognostic factors assessed	Outcome measure of early functional recovery	Timepoint of assessment	Results Factors significantly associated with early functional recovery ($p < 0.005$)
Kennedy, Hanna et al. 2006 (48)	Canada, 1 public	THA, TKA	152	Patient-related and surgical	Age Gender BMI No. comorbidities Pre-op WOMAC (pain and function subscales) Pre-op TUG Pre-op 6MWT Site of arthroplasty	TUG 6MWT WOMAC (pain and function)	Not standardised, 1st time point occurred at hospital discharge (usually 1 week post-op)	Predictors of TUG - Gender (p< 0.003)^ - Pre-op TUG (p<0.001)^ - Site of arthroplasty^# Predictors of 6MWT - Gender (p< 0.003)^ - Pre-op 6MWT (p< 0.001)^ - Site of arthroplasty^#
Kennedy, Stratford et al. 2006 (44)	Canada, 1 public	THA, TKA	152	Patient-related and surgical	Age Gender BMI No. comorbidities Site of arthroplasty	LEFS WOMAC (function) 6MWT TUG SCT	Not standardised, 1st time point occurred at hospital discharge (usually 1 week post-op)	Predictors of 6MWT - Site of arthroplasty^# Predictors of TUG - Site of arthroplasty^# Predictors of SCT - Site of arthroplasty^#
Robbins et al. 2014 (43)	Canada, 1 public	TKA	72	Patient-related	Age Gender BMI POD 1 Pain (NRS) POD1 Comorbidity Self Assessment POD 1 Pain Catastrophising Scale POD 1 contralateral lower limb strength	TUG WOMAC (function)	POD 3	Predictors of TUG - Age (p <0.01)* - Comorbidity scale (p= 0.02)* Predictors of WOMAC - Pain severity (p= 0.02)*

Author Year of publication	Country, number of sites, hospital funding	Surgery type	Population n=	Factor type	Individual potential prognostic factors assessed	Outcome measure of early functional recovery	Timepoint of assessment	Results Factors significantly associated with early functional recovery (p< 0.005)
Hoogeboom et al. 2015 (36)	USA, 1 private	TKA	193	Patient-related and surgical	Age Gender BMI Marital status Employment status Blood loss Tourniquet time Surgeon experience Anaesthesia type Analgesia type	mILAS (0-24) assessed 4 tasks - supine to sitting - sit to stand - walking - stair climbing (considered delayed recovery if score >6 on discharge, or score of 0-6 not attained by afternoon POD2)	Daily per transfer	Age (p< 0.05)* Gender (p< 0.05)* BMI (p< 0.05)* AUC= 0.72 (CI 0.65, 0.80)
Poitras et al. 2015 (27)	Canada, 1 public	THA, TKA, UKA, and hip hemi-arthroplasty	108	Patient-related and surgical	Age Gender BMI Pre-op WOMAC (pain, function and stiffness subscales) Pre-op ILAS (0-50) POD 1 ILAS (0-50) POD 2 ILAS (0-50) Pre-op TUG POD 2 TUG Pre-op PQRS POD1 PQRS POD 2 PQRS POD1 RHDS POD 2 RHDS Arthroplasty site Total vs partial arthroplasty	OARS scale	2 weeks post-op	Pre-op WOMAC (function) (p= 0.002)* Pre-op TUG (p= 0.018)* POD 2 TUG (p< 0.001)*

Author Year of publication	Country, number of sites, hospital funding	Surgery type	Population n=	Factor type	Individual potential prognostic factors assessed	Outcome measure of early functional recovery	Timepoint of assessment	Results Factors significantly associated with early functional recovery ($p < 0.005$)
Oosting et al. 2016 (30)	Netherlands, 1 public	THA	315	Patient-related	Age Gender BMI Charnley class RAPT score Pre-op TUG Pre-op 2MWT Pre-op HGS Pre-op 10mWT	mILAS (0-6) assessed walking ability only (considered delayed recovery if > 4 days to achieve score of 0)	NR	<u>Analysis 1</u> Age[#] Charnley class[#] Pre-op TUG[#] Pre-op 10mWT[#] AUC= 0.85 (CI 0.79, 0.91) <u>Analysis 2</u> Age# Charnley class# pre-op 10mWT[#] Pre-op HGS[#] Surgical approach[#] AUC= 0.88 (CI 0.83, 0.92)
Elings et al. 2016 (49)	Netherlands, 2 public	THA	154[A] 271[B]	Patient-related	Age Gender BMI ASA grade Charnley class Pre-op WOMAC (pain, function and stiffness subscales) Pre-op pain (NRS) Pre-op TUG Pre-op 6MWT Lower limb strength Lower limb power Patient-reported walking capacity	mILAS (0-24) assessed 4 tasks - supine to sitting - sitting to supine - sit to stand - walking (considered delayed recovery if >5 days to achieve score of 0-1)	Daily	Age ($p < 0.05$)* Gender ($p < 0.05$)* BMI ($p < 0.05$)* ASA grade ($p < 0.05$)* Charnley class ($p < 0.05$)* Pre-op TUG ($p < 0.05$)* AUC= 0.82 (CI 0.74, 0.90)

[A] Data set A, [B] Data set B**, AUC:** area under the curve, **ASA** American Society of Anesthesiologists**, BMI** body mass index**, HGS** hand grip strength, **ILAS** Iowa Level of Assistance Scale**, mILAS** modified Iowa Level of Assistance Scale**, NR** not reported, **NRS** Numerical Rating Scale**, OARS** Older American Resources and Services, **POD** post-operative day**, PQRS** Post-operative Quality of Recovery Scale**, RHDS** Readiness for Hospital Discharge Scale, **THA** total hip arthroplasty, **TKA** total knee arthroplasty**, TUG** Timed Up and Go**, UKA** Unicompartmental knee arthroplasty**, WOMAC** Western Ontario and McMaster Universities Osteoarthritis Index**, 2MWT** 2 Minute Walk Test**, 6MWT** 6 Minute Walk Test, **10mWT** 10 metre Walk Test

* *p* value is a result of multiple regression analysis, ^ *p* value is a result of hierarchical linear modelling, [#] *p* value not reported, but stated to be a significant predictor

The studies presented in Table 2 assessed a variety of patient-related characteristics. However, their findings, in conjunction with those of the aforementioned systematic review (37), indicate conflicting evidence for associations between early functional recovery following THA and TKA and factors including age, gender, BMI and comorbidity status. Amongst these studies, comorbidity status was determined using several different tools. A significant association between early functional recovery following THA and TKA and comorbidity status was reported in studies that assessed comorbidity status using Charnley class and the Comorbidity Self-assessment Scale (Table 2). However, in all three studies where it was examined as a potential prognostic factor, the number of comorbidities was not found to be significantly associated with inpatient functional recovery (44,46,48). For American Society of Anesthesiologists grade (ASA), one study reported a significant association with inpatient functional recovery (49), and one study did not (47). Pre-operative function, however, especially when assessed by objective performance measures, was consistently associated with early post-operative function, in all five studies where it was examined (27,30,46,48,49).

Few studies considered the association between individual surgical factors and early functional recovery. The relationship between arthroplasty site and early functional recovery is unclear. Although reported by the authors to be a significant factor in two studies (44,48), the level of significance was not reported nor determinable. Only one other study (36) was located that assessed individual surgical factors. That study found no association between early functional recovery and potential prognostic factors including blood loss, tourniquet time, surgeon experience, method of anaesthesia and type of analgesia usage (36). However, the addition of surgeon experience did improve the predictive value of their base prognostic model, comprised of patient-related characteristics.

Including the studies examined in the systematic review undertaken by Elings et al (37) and those listed in Table 2, early functional recovery has been assessed via nine different outcome measures, and assessment time points also varied significantly. The modified Iowa Level of Assistance Scale, whilst appropriate for assessing early functional recovery, was not implemented in a standardised manner in each of the three studies where it was employed (Table 2), thus potentially compromising its validity, the generalisability of results, and the ability to compare outcomes between studies.

With regard to the methodologies of the studies discussed above, there are several potential confounding factors. Most studies reported the use of standardised physiotherapy protocols. However, several studies did not report standardised peri-operative or post-operative pathways (30,43,46,48), whilst other studies lacked adequate detail to determine which components of their peri-operative pathway had been standardised (36,44,49). Some studies did not consider pre-operative function (36,43,44,47), patient comorbidity (27,36), or severity of comorbidities (44,46,48). Hence, pre-operative function, severity or presence of comorbidity and peri-operative or post-operative variables must be considered as potentially confounding factors in these studies. Further limitations were identified in two studies (44,48). These include the lack of a standardised schedule for assessment of outcome measures, a large quantity of missing data due to patient attrition over the course of the study, and the numbers of participants assessed at each time point not having been reported; thus potentially compromising the validity of their results.

Factors associated with length of stay following THA and TKA

It is well documented that LOS following THA and TKA can be significantly reduced by the implementation of ERP (10,11,14,15,16,22). To gain an overview of individual factors which may be associated with LOS following THA and TKA, an additional narrative review was undertaken. The PubMed database was searched for literature which included the keywords “predict”, “length of stay” and “arthroplasty” within title or abstract. The wildcard function was also employed for the keywords “predict” and “arthroplasty”. All studies that assessed the potential prognostic relationship between patient-related or surgical factors and LOS following primary, unilateral THA or TKA surgery were reviewed.

Only one systematic review could be identified which examined potential prognostic factors for LOS (37). This previously mentioned systematic review undertaken by Elings et al. (37) investigated pre-operative patient-related predictors of LOS following THA. Based on the findings of twelve studies published up until April 2014, a strong level of evidence was determined for higher ASA grade, increased number of comorbidities, and the presence of heart or lung disease as predictive of longer LOS in patients following THA (37). However, of these twelve studies, only one provided adequate detail of the peri-operative and post-operative pathway (50), thus the results of the other studies may be confounded by surgical variables. A single study (51) reported use of discharge criteria to determine LOS, and all but two studies (51,52) failed to describe how the dependent variable (LOS) was assessed. Two of the twelve studies (52,53) considered pre-operative physical or functional status amongst their potential predictor variables. The recommendations of this systematic review included further research with adequate detail regarding clinical pathways (e.g. pre-operative education, surgical technique, anaesthesia methods, post-operative pain management and physiotherapy protocols) to allow pooling of findings regarding specific factors (37).

Several other studies examining potential prognostic factors for LOS which were not included in the systematic review conducted by Elings et al (37) were identified during the narrative review. These additional studies were published subsequent to the cut-off date of April 2014 of the aforementioned systematic review (37), or did not meet the inclusion criteria of the aforementioned systematic review (37) ie: examined potential prognostic factors for LOS following TKA. A summary of the findings of these additional studies is presented in Table 3.

Table 3: Factors associated with length of stay following total hip and knee arthroplasty

Author Year of publication	Country, number of sites, hospital funding	Surgery type	Population n=	Factor type	Individual potential prognostic factors assessed	Outcome Measure Discharge Criteria	Assessment of discharge readiness or discharge criteria	Results Factors significantly associated with length of stay (p< 0.005)
Husted et al. 2008 (9)	Denmark, 1 public	THA, TKA	712	Patient-related and surgical	Age Gender BMI Living situation No. comorbidities Smoking status Pre-op walking aid Pre-op opioid use ASA grade Pre-op Hb Surgeon Weekday of surgery Surgery case number Blood loss Need for blood transfusion No. units transfused DOS mobilisation	LOS (no. full days measured from 0700 DOSA) LOS (less than or equal to 3 days) Discharge criteria: Independent -transfers in/out of bed - sit to stand - mobility using crutches or better, Adequate pain relief Accepting of discharge	Twice daily at 0900 and 1400	Age (p= 0.01)* Gender (p= 0.01)* Living alone (p= 0.02)* Pre-op use of walking aids (p= 0.04)* ASA grade (p= 0.04)* Weekday of surgery (p= 0.001)* Need for blood transfusion (p= 0.001)*
Crawford et al. 2011 (54)	USA, 1 private (Army Hospital)	TKA	383	Patient-related and surgical	Age Gender BMI ASA grade Surgeon Year of surgery Weekday of surgery	LOS (no. days) Discharge criteria: NR	NR assume daily	Age (p= 0.003)^ BMI (p= 0.013)^ ASA grade (p= 0.01)^ Year of surgery (p< 0.001)^ Weekday of surgery (p= 0.01)^
Napier et al. 2013 (55)	UK, 1 public	THA, TKA	535	Patient-related and surgical	Age Gender BMI ASA grade Pre-op Hb Weekday of surgery	LOS Discharge criteria: NR	NR	For THA and TKA Age* NR Gender* NR ASA grade* NR BMI* (TKA only)

Author Year of publication	Country, number of sites, hospital funding	Surgery type	Population n=	Factor type	Individual potential prognostic factors assessed	Outcome Measure Discharge Criteria	Assessment of discharge readiness or discharge criteria	Results Factors significantly associated with length of stay (p< 0.005)
Holm et al. 2014 (29)	Denmark, 2 public	THA, TKA	150	Patient-related	Age Gender BMI Pre-op ipsilateral lower limb power Pre-op TUG Pre-op 10mWT Pre-op resting pain (56) Pre-op pain with performance tests (56) PAS HOOS/KOOS	LOS (no. nights) Discharge readiness determined by: Independence with: - personal care - dressing - transfers in/out of bed - sit to stand - walking with crutches Adequate pain relief (VAS< 50mm)	Twice daily at 0900 and 1400	Age (p= 0.002)* for THA Age (p= 0.03)* for TKA
Robbins et al. 2014 (43)	Canada, 1 public	TKA	72	Patient-related	Age Gender BMI POD 1 Pain (NRS) POD1 Comorbidity Self Assessment POD 1 Pain Catastrophising Scale POD 1 contralateral lower limb strength	LOS (no. days) Discharge criteria: NR	NR assume daily	Age (p <0.01)*
Halawi et al. 2015 (57)	USA, 1 private	THA	112	Patient-related	Age Gender BMI Pre-op pain (NRS) No. of comorbidities Pre-op walking aid Previous THA or TKA Prior ECF admission Expected discharge destination Care giver at home	LOS (no. nights)> 2 Discharge criteria: Medically stable, adequate pain control, able to void, tolerating oral diet, no surgical concerns, deemed functionally appropriate by PT/OT for discharge destination	NR assume daily	Pre-op pain (p= 0.001)* Expected discharge to ECF (p< 0.001)*

Author Year of publication	Country, number of sites, hospital funding	Surgery type	Population n=	Factor type	Individual potential prognostic factors assessed	Outcome Measure Discharge Criteria	Assessment of discharge readiness or discharge criteria	Results Factors significantly associated with length of stay (p< 0.005)
Poitras et al. 2015 (27)	Canada, 1 public	THA, TKA, UKA, and hip hemi-arthroplasty	108	Patient-related and surgical	Age Gender BMI Pre-op WOMAC (pain, function and stiffness) Pre-op, POD1, POD 2 ILAS (0-50) Pre-op, POD 2 TUG Pre-op, POD1, POD 2 PQRS (function) POD1, POD 2 RHDS (personal status) Arthroplasty site Total vs partial arthroplasty	LOS Discharge criteria: NR	NR assume daily	Pre-op TUG (p <0.001)* POD 2 TUG (p <0.001)*
van den Belt et al. 2015 (58)	Netherlands,1 public	TKA	240		Age Gender BMI ASA grade Smoking status Pre-op analgesia Pre-op Hb Surgeon Weekday of surgery Anaesthesia type Surgery duration Tourniquet duration Patella prosthesis Blood loss Blood transfusion No. physiotherapy sessions Post-op pain Wound ooze ROM Quads power	Discharge criteria: Independence with - transfers in/out of bed - sit to stand - walking with aid - stairs (if necessary for discharge) Active knee flexion > 60 Passive knee extension 0 Quads power greater or equal to 3 No/minimal wound ooze Adequate pain control (NRS less or equal to 5)	Daily	ASA grade (p< 0.001)* Wound ooze (p< 0.001)* ROM at day 0 (p< 0.001)*

Author Year of publication	Country, number of sites, hospital funding	Surgery type	Population n=	Factor type	Individual potential prognostic factors assessed	Outcome Measure Discharge Criteria	Assessment of discharge readiness or discharge criteria	Results Factors significantly associated with length of stay (p< 0.005)
Petis et al. 2016 (56)	Canada, 1 public	THA	120	Patient-related and surgical	Age Gender BMI Age-adjusted Charlson Comorbidity Index Diagnosis necessitating THA Pre-op TUG Operative side Surgical approach Surgery duration Duration of PACU admission	LOS > 48 hours Discharge criteria: NR	NR assume daily	Pre-op TUG (p= 0.043)*
Sibia et al. 2016 (59)	USA, 1 private	THA	273	Patient-related and surgical	Age Gender BMI ASA grade Comorbidity Surgical approach Anaesthesia type Surgery duration Blood loss DOS mobilisation	LOS> 2 days Discharge criteria: Medical clearance Physio clearance using standardised criteria (NR)	NR assume daily	Age (p< 0.001)* Gender (p= 0.031)* BMI (p= 0.005)* ASA grade (p= 0.029)* Presence CAD (p= 0.013)* After adjusting for age, gender and BMI: Surgical approach (p< 0.001)* Anaesthesia type (p= 0.007)* Surgery duration (p< 0.001)* Blood loss (p= 0.001)*

ASA American Society of Anesthesiologists**, BMI** body mass index**, CAD** coronary artery disease**, DOS** day of surgery, **DOSA** day of surgery admission, **ECF** extended care facility, **Hb** haemaglobin, **HOOS** Hip disability and Osteoarthritis Outcome Score, **KOOS** Knee injury and Osteoarthritis Outcome Score, **LOS** length of stay, **NR** not reported, **NRS** Numerical Rating Scale, **OT** occupational therapist, **PACU** Post-Anaesthetic Care Unit, **PAS** Psychogeriatric Assessment Scales, **POD** post-operative day**, PQRS** Post-operative Quality of Recovery Scale**, PT** physiotherapist, **RHDS** Readiness for Hospital Discharge Scale, **ROM** range of motion, **THA** total hip arthroplasty, **TKA** total knee arthroplasty**, TUG** Timed Up and Go**, VAS** Visual Analogue Scale, **10mWT** 10 metre Walk Test
* *p* value is a result of multiple regression analysis ^ *p* value is a result of linear regression analysis

The studies summarised in Table 3 provided conflicting evidence for associations between hospital LOS following THA or TKA and patient-related factors including age, gender, BMI, pre-operative pain, pre-operative function and pre-operative use of a walking aid. Limited evidence supported associations between LOS and living alone, expected discharge destination and presence of coronary artery disease (Table 3). However, comorbidity, assessed by ASA grade, was reported to be significantly associated with LOS in all five studies that included it as a variable, with all but one study reporting *p* values of statistical significance (<0.05) (Table 3).

Conflicting evidence was also found for associations between several individual surgical factors and LOS following THA and TKA. These included blood loss, blood transfusion requirement, surgery duration, anaesthetic method and THA surgical approach (Table 3). Conflicting evidence was also reported for the association between LOS and surgery occurring later in the week i.e., Thursdays and Fridays (Table 3). It was suggested that LOS may be impacted by the reduced availability of weekend services such as physiotherapy. Post-operatively, range of motion on day of surgery and wound ooze were found to be associated with longer LOS following TKA (Table 3).

Methodologically, of the ten studies presented in Table 3, five studies did not use discharge criteria to determine LOS, whilst two studies provided no detail of their surgical pathway (43, 54), and a further three studies indicated a generally standardised care pathway only (27, 55,56). Moreover, a further two studies did not examine patient comorbidity as a potential prognostic factor (27,29). Thus, these potentially confounding factors must be considered when interpreting the study results.

A further study of 215 participants examined factors that necessitated patients' hospitalisation following THA and TKA. Despite implementation of an ERP, post-operative clinical symptoms frequently associated with longer LOS included pain, dizziness and general weakness (12). Less commonly, nausea and vomiting, post-operative delirium and sedation also delayed discharge (12). Post-operative complications such as urinary retention requiring catheterisation, and the need for ongoing intravenous therapy or blood transfusion were also associated with longer LOS (12). Symptoms or complications such as these may be related, in part, to the surgical factors employed in existing care pathways.

Although associated with post-operative functional recovery, LOS is also subject to multiple other variables; both internal and external to the healthcare organisation. Longer LOS following THA and TKA was linked with logistical factors including inadequate social support (55); and delays in the delivery of services such as physiotherapy and radiology, which prolonged discharge in up to 20% of patients (12). Economic drivers such as funding for diagnostic related groups (60) or hospital policy (61) may also dictate LOS. As LOS following THA and TKA has the potential to be influenced by a broad range of factors other than the physical function of the patient, it is not necessarily an accurate reflection of early functional outcomes, patient discharge readiness or the effectiveness of ERP.

Conclusions

In summary, previous studies of early functional recovery have primarily examined the potential prognostic value of conventional patient-related factors. Pre-operative function, particularly when assessed by objective performance measures appears to be most consistently associated with early post-operative function. The influence of other patient-related factors is unclear. Nevertheless, these patient-related factors alone only partially explain the variance in functional recovery following THA or TKA (30). The relationship between individual surgical factors and early functional recovery has rarely been assessed, and thus further research on this topic is warranted. Inconsistent findings and heterogeneity in both study quality and methodology have thus far precluded definitive conclusions regarding the factors most important to recovery in the early post-operative period (37).

Aside from comorbidity determined by ASA grade, the evidence for factors associated with LOS is conflicting. However, LOS does appear to be subject to patient-related, surgical and organisational factors. Inadequate detail of interventions, and the methodology used to determine LOS, limit the interpretation of these results. Finally, only one systematic review was identified regarding patient-related predictors of inpatient recovery and LOS following primary THA (37). A systematic review of surgical factors that may predict inpatient recovery following THA or TKA is yet to be undertaken. The aforementioned findings from previous research highlight a significant gap in the literature regarding potential prognostic factors for early functional recovery and LOS following THA and TKA.

Whilst it is recognised that ERP comprise multiple aspects of the surgical pathway; and optimisation of all of these individual aspects is likely to yield maximal results; the role of individual surgical variables warrants further research. This may enable identification of particular aspects of the surgical pathway which are most strongly associated with early functional recovery; thus directing attention to these pathway components, when standardisation of the entire pathway may not be practical due to variations in the context, culture or environment of different ERP settings. On this basis, the systematic review and prospective cohort study completed within the current program of research and reported in the following chapters of this thesis aim to expand upon existing knowledge regarding inpatient functional recovery, and further explore the strengths of the relationships between a comprehensive set of patient and surgical variables, and early functional recovery following primary, unilateral lower limb arthroplasty. The prognostic models created in this program of research, must then be validated in future prospective cohorts, and undergo impact analysis to assess their impact on clinical outcomes. Ultimately, it is hoped that these models may assist clinicians to anticipate patient needs and further refine aspects of service delivery thus potentially optimising both patient and organisational outcomes.

CHAPTER 3: PROGNOSTIC FACTORS FOR INPATIENT FUNCTIONAL RECOVERY FOLLOWING TOTAL HIP AND KNEE ARTHROPLASTY: A SYSTEMATIC REVIEW

Preface

As identified in Chapter 2, few studies have specifically examined early post-operative functional recovery as an outcome following total hip arthroplasty (THA) or total knee arthroplasty (TKA), using valid measures. While studies have considered achievement of hospital-specific functional discharge criteria, these have been implemented sporadically, and constitute neither a standardised nor validated outcome measure. Importantly, the evidence for factors associated with early functional recovery following lower limb arthroplasty is generally inconsistent, and prior to the current program of research, inpatient functional recovery had been investigated by only a single systematic review. This systematic review by Elings et al (37) on patient-related factors associated with inpatient functional recovery following THA reported findings based on the evidence of just two studies. A systematic review of surgical factors that may be associated with inpatient functional recovery following THA or TKA had not previously been undertaken. Thus, a further systematic review was necessary to identify, synthesise and analyse all available research examining patient-related and surgical prognostic factors for early functional recovery following both THA and TKA, using validated outcome measures.

The systematic review documented in this chapter was published in the peer-reviewed journal, Acta Orthopaedica, and is formatted according to the journal's guidelines. A copy of the published manuscript is provided in Appendix I.

Hewlett-Smith N, Pope R, Furness J, Simas V, Hing W. Prognostic factors for inpatient functional recovery following total hip and knee arthroplasty: a systematic review. Acta Orthopaedica 2020; 91. DOI: 10.1080/17453674.2020.1744852

Abstract

Background and purpose: Essential for safe and timely hospital discharge, inpatient functional recovery following lower limb arthroplasty is also variable. A previous systematic review reported moderate and conflicting levels of evidence regarding patient-related predictors of inpatient recovery for primary total hip arthroplasty (THA). A systematic review of surgical prognostic factors for inpatient recovery following THA or total knee arthroplasty (TKA) is yet to be undertaken. We identified patient and surgical prognostic factors for inpatient functional recovery following THA and TKA; determined whether inpatient functional recovery varies between these procedures; and established whether validated outcome measures relevant to the patient's functional requirements for hospital discharge are routinely assessed.

Patients and methods: Critical Appraisal Skills Programme checklists assessed methodological quality, and a best-evidence synthesis approach determined the levels of evidence supporting individual prognostic factors. PubMed, CINAHL, Embase, Scopus and PEDro databases were searched from inception to May 2019. Included studies examined patient or surgical prognostic factors and a validated measure of postoperative function within 2 weeks of primary, unilateral THA or TKA.

Results: Comorbidity status and preoperative function are supported by a strong level evidence for TKA. For THA, no strong level of evidence was found for patient-related prognostic factors, and no surgical factors were independently prognostic for either arthroplasty site. Limited evidence supports fast-track protocols in the TKA population.

Interpretation: Preoperative screening and optimization is recommended. Assessment of Enhanced Recovery Pathways using validated outcome measures appropriate for the early postoperative period is warranted.

Introduction

The International Classification of Function, Disability and Health (25) describes the interdependent relationship among function, activity, and participation. Following lower limb arthroplasty, functional recovery is key to the independent performance of fundamental activities of daily living (ADL) such as walking, transferring in and out of bed, and climbing stairs; achieving these milestones is necessary for safe and timely hospital discharge (27, 28,36). Inability to perform basic ADL increases the patient's risk of social isolation, falls, and the need for additional resources such as rehabilitation and community services (27).

To promote rapid recovery, multimodal Enhanced Recovery Pathways (ERP) are increasingly used for lower limb arthroplasty (15). However, the success of these pathways is primarily assessed via non patient-centric measures including morbidity and mortality, readmission rates, length of stay (LOS), and organizational economic savings (13). Functional recovery is linked to discharge destination, longer-term functional outcomes, quality of life (31), patient satisfaction (32), LOS, and associated costs (9,10,20). However, few studies have specifically examined inpatient functional recovery as an outcome following lower limb arthroplasty, using valid measures.

While studies have considered achievement of hospital-specific functional discharge criteria, these constitute neither a standardized nor a validated outcome measure. Whilst LOS may be influenced by wide-ranging factors (9,10,12,49,55,60), inpatient functional recovery is commonly thought to be primarily affected by patient and surgical factors.

Surprisingly, inpatient functional recovery has been investigated by a single systematic review. Based on the results of 2 studies, Elings et al. (37) reported moderate and conflicting levels of evidence regarding the association between patient-related factors and inpatient functional recovery. Therefore, this systematic review examines the evidence for patient and surgical prognostic factors for inpatient functional recovery following both total hip arthroplasty (THA) and total knee arthroplasty (TKA); determines whether inpatient functional recovery varies between these procedures; and identifies whether validated outcome measures relevant to the patient's functional requirements for hospital discharge are routinely assessed. The identification of surgical prognostic factors may provide an opportunity to refine ERP, whilst patient-related factors may aid in identifying those at risk of delayed recovery, enabling medical optimization, prehabilitation, and early discharge planning (30).

Method

The systematic review protocol was registered with PROSPERO (PROSPERO Registration: CRD42019136206), and reporting is in accordance with the PRISMA statement. A comprehensive search of PubMed, CINAHL, Embase, Scopus, and PEDro databases was undertaken on 31st May 2019. The search strategy included key search terms relating to prognostic factors, hip and knee arthroplasty, and function. Subject headings specific to individual databases were utilized, and wildcards employed. No date range or language filters were applied. The PubMed/MEDLINE search strategy is presented in Appendix II. Reference lists were also examined to capture all potentially eligible publications. Eligibility criteria (Table 4) were established and applied to the search results during initial screening of titles and abstracts. Final selection of articles based on full text review was performed independently by 2 reviewers. Differences were resolved by consensus.

Table 4: Eligibility criteria

Criteria	Inclusion	Exclusion
Population	- Humans undergoing primary elective total hip or knee arthroplasty	- Bilateral total hip or knee arthroplasty - Unicompartmental knee arthroplasty - Hip joint re-surfacing - Arthroplasty performed secondary to fracture (trauma or pathological)
Context	- Australian and international studies carried out in public and private hospital settings	- Studies not carried out within a public or private hospital - Articles not reporting primary research
Language	- All languages	- Studies where language translation was not possible. However, these studies were noted for completeness, prior to exclusion
Recency of publication	- All date periods preceding the search date	
TimepPeriod	- Studies examining outcomes in the early postoperative period (less than or equal to 2 weeks postoperatively)	- Studies where the postoperative time point at which outcome measures were assessed is not specified or was > 2 weeks
Prognostic factors	- Studies examining the relationship between one or more surgical or patient-related prognostic factors and functional performance or patient- reported outcome measures	- Studies where the prognostic factors of interest pertained only to determining the efficacy of a treatment intervention, the specific properties of the prosthesis used or patient genetic, blood, or radiological markers
Outcomes	- Studies examining at least one validated functional performance or patient-reported outcome measure indicating postoperative functional recovery	

Critical Appraisal Skills Programme (CASP) (62-64) checklists were used to address the methodological quality of the differing study designs and examine external validity, internal validity (bias), internal validity (confounding), and statistical power. To grade methodological quality, a scoring system was devised by the reviewers, and applied to each CASP checklist. Subsequently, Questions 7 and 8 of each checklist, and Question 12 of the Cohort Studies checklist were modified to elicit a 'Yes', 'No' or 'Can't tell' response (Appendix III). For each checklist question, a 'Yes' response scored 1, and a response of 'Can't tell' or 'No' scored 0; for questions involving a 2-part answer, parts (a) and (b) were scored separately. Using this system, the CASP checklists for Randomised Controlled Trials, Case Control Studies, and Cohort Studies had a maximum possible score of 11, 12 and 14, respectively. Scores were converted to a percentage and ranges were determined (by the reviewers) to reflect methodological quality as follows: <30% low quality, 31-65% medium quality, and >65% high quality. Studies were independently appraised by 2 reviewers, and Cohen's Kappa (κ) (65) assessed level of agreement; differences were resolved by discussion and consensus.

Extracted data was tabulated, including: study design, context, sample size, demographics, arthroplasty site, prognostic factors, validated measures of postoperative functional recovery, and the time points at which these were assessed. Meta-analysis was not possible due to the methodological heterogeneity of included studies, therefore a best evidence synthesis approach was employed. Evidence levels were ranked as follows: strong evidence is provided by ≥2 studies with low risk of bias and by generally consistent findings in all studies (≥75% of the studies reported consistent findings); moderate evidence is provided by 1 low risk of bias study and ≥2 moderate/high risk of bias studies or by ≥2 moderate/ high risk of bias studies and by generally consistent findings in all studies (≥75%); limited evidence is provided by ≥1 moderate/high risk of bias studies or 1 low risk of bias study and by generally consistent findings (≥75%); conflicting evidence is provided by conflicting findings (<75% of the studies reported consistent findings) (66).

Results

The search identified 7724 records and, following screening, 17 studies were included (Figure 2).

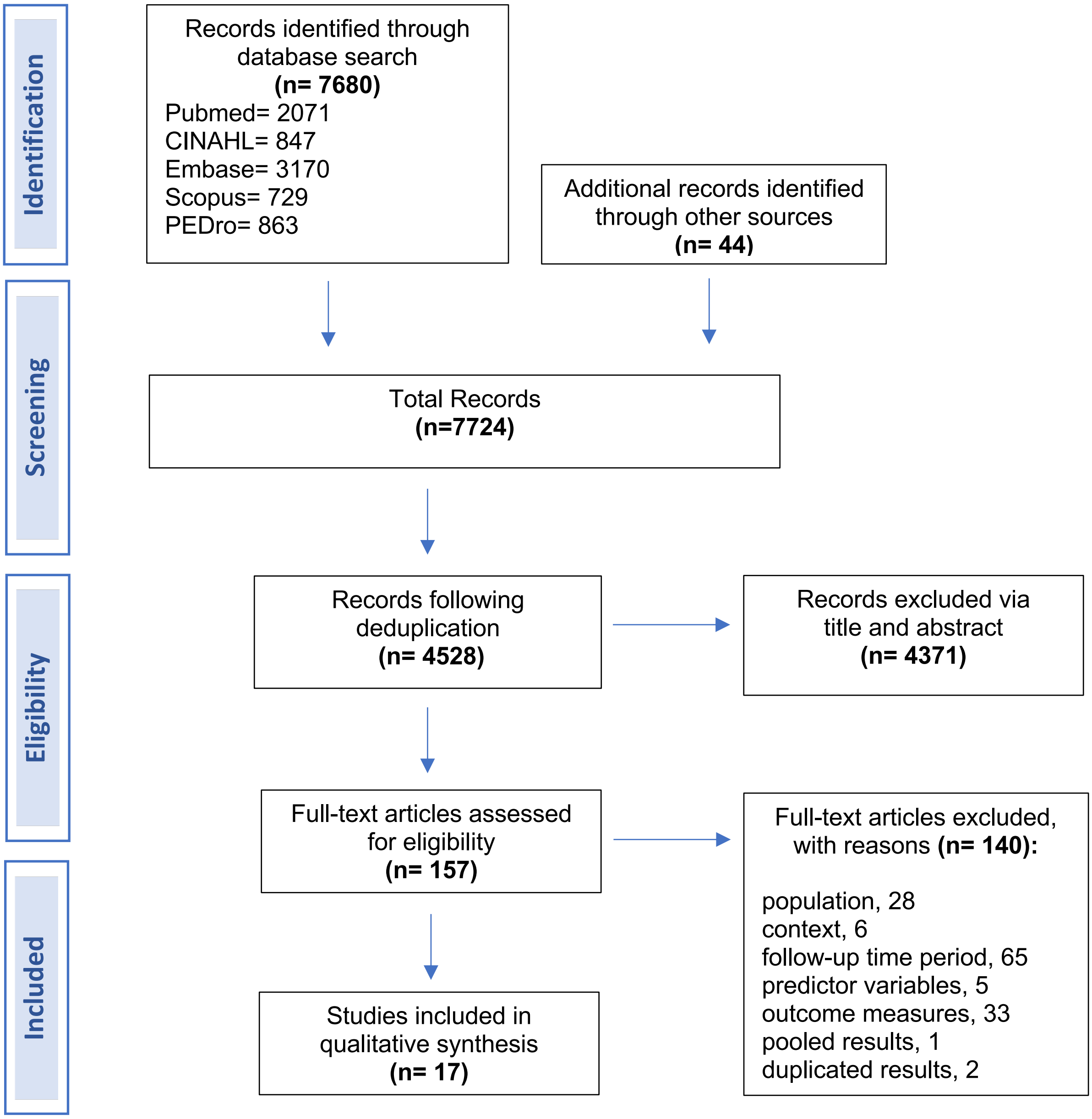

Figure 2: PRISMA flow diagram

These incorporated 1171 THA and 1662 TKA procedures. 8 studies investigated THA, 8 TKA, and 1 both procedures (Table 5). 12 studies examined patient-related factors (Table 6) and 9 studies investigated surgical factors (Table 7). Numerous tools evaluated comorbidity status and preoperative function. Postoperative functional recovery was assessed via 14 different validated functional performance and patient-reported outcome measures (PROM). Assessment time points varied significantly between studies within the 2-week postoperative period.

Critical appraisal results are presented in Appendix IV; 7 studies were rated as high methodological quality, 7 as medium quality, and 3 as low quality. There was strong level of agreement between the two reviewers' judgements ($\kappa = 0.944$, $p < 0.001$). The best-evidence synthesis for prognostic factors for early functional recovery following THA and TKA is presented in Tables 8 and 9 respectively.

The heterogeneity of outcome measures employed in the included studies is presented in Table 10. Only 7 studies utilized objective outcome measures that assess key functional tasks representative of ADL required for discharge. The Modified Barthel Index (MBI) (67), Iowa Level of Assistance Scale (ILAS) (28) and modified Iowa Level of Assistance Scale (mILAS) (45) each assess tasks including bed or chair transfers, ambulation, stair climbing, and the amount of assistance required for their achievement. However, the mILAS was further modified (from that published by Oldmeadow et al.) (45), in 2 studies (49,69) and only partially implemented in all 4 studies where it was assessed, potentially compromising its validity, the generalizability of results and also the ability to compare outcomes between studies. Morri et al. (70) describes the scoring method for the ILAS inaccurately, casting doubt on the validity of its implementation.

Table 5: Study characteristics

Author Year of publication	Study design	Country, number of sites hospital funding source	Surgery type	Population n=	Mean age (years), (SD) Range	% Female	Prognostic factors	Validated outcome measures
Bade et al. 2014 (71)	RCT (2x pooled)	United States, 1 public	TKA	64	64.6, (8.5) NR	50	Patient	TUG
Carli et al. 2010 (72)	RCT	Canada, 1 public	TKA	40	71, NR 55-85	73	Patient Surgical	Change in 2MWT (POD3-POD1)
Carmichael et al. 2013 (73)	RCT	Canada, 1 public	THA	47	60.2_{pooled}, $(12.8)_{\text{pooled}}$ NR	39	Surgical	WOMAC function
Den Hertog et al. 2012 (60)	CCS	Germany, 1 NR	TKA	147	67.4_{pooled}, $(8.1)_{\text{pooled}}$ NR	71	Surgical	WOMAC (0-10) osteoarthritis index AKSS
Elings et al. 2016 (49)	PCS	Netherlands, 2 public	THA	154[A] 271[B]	70.5_{pooled}, $(9.0)_{\text{pooled}}$ NR	70 69	Patient	mILAS
Fransen et al. 2018 (74)	RCT	Netherlands, 1 public	TKA	50	62.5_{pooled}, $(8.1)_{\text{pooled}}$ NR	60	Surgical	TUG SF-12 KOOS
Hoogeboom et al. 2015 (36)	PCS	United States, 1 private	TKA	193	65, (10) NR	64	Patient Surgical	mILAS
Ilfeld et al. 2008 (61)	RCT	United States, 2 private	TKA	50	65, NR 60-70	58	Surgical	6MWT
Kennedy et al. 2006 (48)	PCS	Canada, 1 public	THA TKA	152	63.8_{pooled}, $(9.7)_{\text{pooled}}$ NR	49	Patient Surgical	TUG 6MWT WOMAC pain WOMAC function
Kessler and Kafer 2007 (7**5**)	PCS	Germany, 1 public	THA	67	63.6, NR 37-77	45	Patient Surgical	WOMAC pain WOMAC function WOMAC stiffness

Author Year of publication	Study design	Country, number of sites hospital funding source	Surgery type	Population n=	Mean age (years), (SD) Range	% Female	Prognostic factors	Validated outcome measures
Maiorano et al. 2017 (76)	RCS	Italy, 1 private	TKA	353	71.6 $_{pooled}$, (8.2) $_{pooled}$ NR	73	Patient	Change in MBI
Morri et al. 2016 (70)	PCS	Italy, 1 public and private	THA	167	60.8, (12.7) NR	62	Patient	ILAS
Ogonda et al. 2005 (77)	RCT	United Kingdom, 1 public	THA	219	66.6 $_{pooled}$, (10.1) $_{pooled}$ NR	51	Surgical	mILAS 10mWT SCT(ascending) SCT(descending)
Salmon et al. 2001a (78)	PCS	United Kingdom, 2 public	THA	102	69, (11) NR	62	Patient	10mWT 25mWT
Van der Sluis et al. 2017 (69)	PCS	Netherlands, 1 public	TKA	682	70 $_{pooled}$, (9.1) $_{pooled}$ 41-89	73	Patient	mILAS
Wang et al. 1998 (46)	PCS	Australia, 1 private	THA	65	71, NR 47-87	48	Patient	MBI

[A]Data set A, [B]Data set B**, AKSS** American Knee Society Score, **CCS** case control study, **ILAS** Iowa Level of Assistance Scale**, KOOS** Knee injury and Osteoarthritis Outcome Score, **LEFS** Lower Extremity Functional Scale, **mILAS** modified Iowa Level of Assistance Scale, **MBI** Modified Barthel Index, **NR** not reported, **PCS** prospective cohort study, **POD** postoperative day, **RCS** retrospective cohort study, **RCT** randomized controlled trial, **SCT** stair climbing test, **SD** standard deviation, **SF-12** Short form 12 health survey, **THA** total hip arthroplasty, **TKA** total knee arthroplasty**, TUG** Timed Up and Go, **WOMAC** Western Ontario and McMaster Universities Osteoarthritis Index, **2MWT** 2-minute walk test, **6MWT** 6-minute walk test**, 10mWT** 10-meter walk test, **25mWT** 25-meter walk test

Table 6: Patient-related prognostic factors for inpatient functional recovery

Study ID	Surgery type	Individual prognostic factors	Outcomes assessed	Timepoint of assessment	Association with functional outcome (95% CI)	Methodological quality of study
Bade et al. 2014	TKA	Age Sex TUG ^ 6MWT ^	TUG	POD 2	NR NR β: -61 (CI -107- -14) * NR	High
Carli et al. 2010	TKA	Age Body weight ASA grade 2 CHAMPS[#] WOMAC function subscale[#] Knee Society evaluation[#] SF-12[#] Log 2MWT ^ Total walking time[#] (POD1+ POD 2+ POD3)	Change in 2MWT (POD3-POD1)	POD 1, 2, 3	NR β: 0.27 (CI 0.07-0.48)* β: -10.6 (CI -20.8- -0.4)* NR NR NR NR β: 10.3 (CI 3.1-17.5)* β: 0.2 (CI 0.05-0.4)*	High
Elings et al. 2016	THA	Age (>70 years) Sex BMI ASA grade Charnley class WOMAC pain subscale[#] WOMAC stiffness subscale[#] WOMAC function subscale[#] Pain scale[#] Patient-estimated walking capacity (mins) [#] 6MWT ^ Chair-rise time ^ Quads power (dynamometer) ^ TUG ^	mILAS (considered delayed recovery if > 5 days to achieve score of 0-1)	Daily	OR: 1.2 (CI 0.4-3.4)* OR: 0.8 (CI 0.2-2.6)* OR: 2.2 (CI 0.7-7.4)* OR: 1.2 (CI 0.3-4.4)* OR: 6.1 (CI 2.2-17.4)* NR NR NR NR NR NR NR NR OR: 3.1 (CI 1.1-9.0)* AUC= 0.82 (CI 0.7-0.9)	High
Hoogeboom et al. 2015	TKA	Age Sex BMI Marital status Employment status	mILAS (considered delayed recovery if score >6 on discharge or not attained 0-6 by afternoon POD2)	Daily per transfer	OR: 1.08 (CI 1.04-1.1)* OR: 2.1 (CI 1.1-4.0)* OR: 1.1 (CI 1.06-1.2)* NR NR (AUC= 0.72: 0.65, 0.80)	High

Study ID	Surgery type	Individual prognostic factors	Outcomes assessed	Timepoint of assessment	Association with functional outcome (95% CI)	Methodological quality of study
Kennedy et al. 2006	THA, TKA	Age Sex BMI Number of comorbidities TUG ^ 6MWT ^ WOMAC pain subscale# WOMAC function subscale#	TUG 6MWT WOMAC pain WOMAC function	Not standardized 1st time point at hospital DC (generally at 1 week postop)	NR, *ns* NR (except for p ≤ 0.003 TUG and 6MWT at 1 week post-op)* NR, *ns* NR, *ns* NR (except for p ≤ 0.001 TUG at 1 week post-op)* NR (except for p ≤ 0.001 6MWT at 1 week post-op)* NR NR	Medium
Kennedy et al. 2011	THA	Age Sex BMI LEFS# 6MWT ^	6MWT LEFS	Not standardized Appears 1st time point 2 weeks postop	NR, *ns* NR, *ns* NR, *ns* NR, *ns* β: 0.6 (CI 0.3-0.9)* (6MWT, females) β: 0.6 (CI 0.4-0.7)* (6MWT, males)	Low
Kessler and Kafer 2007	THA	Age Sex BMI Affected side WOMAC pain, function and stiffness subscales#	WOMAC pain, function and stiffness ss	POD 10	OR: -0.01 (CI -0.5- 0.5), *ns* OR:-11.9 (CI -22.7- -1.1)* OR -0.2 (CI -1.2- 0.9), *ns* OR: 7.2 (CI -2.7- 17.1), *ns* OR: 0.3 (CI 0.1 - 0.6)*	Medium
Maiorano et al. 2017	*TKA*	Age BMI Charlson index Depressive disorder Other TKA or THA Haemoglobin level MBI^	Change in MBI	POD3 and on discharge from rehab	β: -0.3 (CI -0.4- -0.2)*(females), *ns* (males) NR, *ns* NR, *ns* NR, *ns* NR, *ns* NR, *ns* β: -0.8 (CI -0.9- -0.7)* (females) β: -0.8 (CI -0.9- -0.8)* (males)	Medium

Study ID	Surgery type	Individual prognostic factors	Outcomes assessed	Timepoint of assessment	Association with functional outcome (95% CI)	Methodological quality of study
Morri et al. 2016	THA	Age Sex ASA grade	ILAS	During last 24 hours of hospital stay (LOS 7 days or less)	β: -2.9 (CI -4.8 - -1.0)* β: 0.2 (CI 0.1-0.2)* NR	Low
Salmon et al. 2001a	THA	POMS# WOMAC pain subscale# WOMAC stiffness subscale# WOMAC function subscale#	10mWT 25mWT (inpatient recovery scored as number of days to achieve milestones)	Unclear ? Daily	NR, *ns* NR, *ns* NR, *ns* NR, *ns*	Low
Van der Sluis et al. 2017	TKA	Age Sex BMI ASA grade Charnley class ISAR score Presence of stairs at home TUG ^ DEMMI ^	mILAS functional recovery assessed as number of days to achieve score 0-6: considered delayed recovery if took: > 6 days (1st pathway), 4 days (2nd pathway), 3 days (3rd pathway) Data collected over 9 years; pathway updated over this time frame	Daily	OR: 1.06 (CI 1.04-1.09)* NR OR: 1.04 (CI 1.00-1.08), *ns* OR: 2.5 (CI 1.5-4.0)* NR OR: 1.6 (CI 1.4-2.0)* NR OR: 1.10 (CI 1.06-1.15)* OR: 0.96 (CI 0.95-0.98)*	High
Wang et al. 1998	THA	Age Number of comorbidities MBI ^ Hip strength (dynamometer) ^	MBI (considered extended LOS if not achieving 90 or above by POD 10) Hip strength	POD 3, 5, 8, 10	OR: 3.9 (CI 0.6-27.8), *ns* OR: 2.0 (CI 0.5-7.4), *ns* OR: 6.0 (CI 1.3-28.3)* OR: 4.0 (CI 1.0-16.1), *ns*	Medium

ASA American Society of Anesthesiologists, **BMI** body mass index, **CHAMPS** Community Health Activities Model Program for Seniors, **CI** 95% confidence interval, **DEMMI** de Morton Mobility Index, **ILAS** Iowa Level of Assistance Scale**, ISAR** Identification of Seniors At Risk, **LEFS** Lower Extremity Functional Scale, **MBI** Modified Barthel Index, **mILAS** modified Iowa Level of Assistance Scale, ***ns*** not significant, **NR** not reported**, POD** postoperative day, **POMS** Profile of Mood States, **SF-12** Short form 12 health survey, **THA** total hip arthroplasty, **TKA** total knee arthroplasty**, TUG** Timed Up and Go, **WOMAC** Western Ontario and McMaster Universities Osteoarthritis Index, **2MWT** 2-minute walk test, **6MWT** 6-minute walk test, **10mWT** 10-meter walk test, **25mWT** 25-meter walk test
* indicates significance at 0.05 level, # patient-reported outcome measure (PROM), ^ functional performance measure

Table 7: Surgical prognostic factors for inpatient functional recovery

Study ID	Surgery type	Individual prognostic factors	Outcomes assessed (within 2 week post-operative time frame)	Timepoint of assessment	Association with functional outcome (95% CI)	Methodological quality of study
Carli et al. 2010	TKA	Anaesthesia type - Continuous FNB - Periarticular LIA	Change in 2MWT distance (POD3-POD1)	POD 1, 2, 3	NR (except for p= 0.27), *ns*	High
Carmichael et al. 2013	THA	Analgesia type - Pregabalin/celecoxib - Placebo/placebo	WOMAC pain, function and stiffness subscales	1 week postop	NR	Medium
Den Hertog et al. 2012	TKA	Fast-track protocol[#]	WOMAC function AKSS	POD 5-7	NR (except for p< 0.0001)* NR (except for p< 0.0001)* Results reported for per protocol cohort only. ITT cohort results NR	High
Fransen et al. 2018	TKA	Fast-track protocol[†]	TUG SF-12 KOOS	2 weeks postop	NR (except for p= 0.017)* NR, *ns* NR, *ns*	Medium
Hoogeboom et al. 2015	TKA	Blood loss Tourniquet time Surgeon experience Anaesthesia type - continuous FNB - single shot FNB - general - spinal Analgesia type - morphine use	mILAS (considered delayed recovery if score >6 on discharge or not attained 0-6 by afternoon POD2)	Daily per transfer	OR: 1.00 (CI 0.99-1.01), *ns* OR: 0.99 (CI 0.98-1.01), *ns* OR: 0.36 (CI 0.20-0.66), *ns* NR NR NR NR OR: 0.95 (CI 0.45-2.01), *ns*	High
Ilfeld et al. 2008	TKA	Anaesthesia type - overnight FNB 4-day ambulatory FNB	6MWT	Afternoon POD1	OR: 1.2 (CI 0.7-1.9), *ns*	Medium

Study ID	Surgery type	Individual prognostic factors	Outcomes assessed (within 2 week post-operative time frame)	Timepoint of assessment	Association with functional outcome (95% CI)	Methodological quality of study
Kennedy et al. 2006	TKA, THA	Site of arthroplasty	TUG 6MWT WOMAC pain WOMAC function	Variable	NR (for TUG and 6mWT at 1 week post-op)§ NR NR§ NR, *ns*	Medium
Kessler and Kafer 2007	THA	Anchorage of implant Duration of surgery	WOMAC pain, function and stiffness subscales	POD 10	OR: 4.4 (CI -2.2-11.1), *ns* OR: -0.16 (CI -0.46-0.14), *ns*	Medium
Ogonda et al. 2005	THA	Incision size	mILAS (3x tasks) - supine to sit - sit to stand - walking 10mWT SCT (ascending) SCT (descending)	POD 2	 NR (except for p= 0.27), *ns* NR (except for p= 0.28), *ns* NR (except for p= 0.49), *ns* NR (except for p= 0.97), *ns* NR (except for p= 0.83), *ns* NR (except for p= 0.22), *ns*	High

AKSS American Knee Society Score, **CI** 95% confidence interval, **FNB** femoral nerve block, **KOOS** Knee injury and Osteoarthritis Outcome Score, **LIA** local infiltration analgesia, **mILAS** modified Iowa Level of Assistance scale, ***ns*** not significant, **NR** not reported**, POD** post-operative day, **SCT** Stair Climbing Test, **SF-12** Short Form-12 health survey, **THA** total hip arthroplasty, **TKA** total knee arthroplasty**, TUG** Timed Up and Go, **WOMAC** Western Ontario and McMaster Universities Osteoarthritis Index, **2MWT** 2-minute walk test, **6MWT** 6-minute walk test **10mWT** 10-meter walk test.

Den Hertog# Fast-track rehabilitation versus standard rehabilitation: day of surgery mobilization versus mobilization day 2 postop, 2-hour versus 1-hour physiotherapy sessions, group therapy focusing on activities of daily living (ADL) versus individual. Fast-track group also received positive affirmation, encouraged comparison of progress with other patients (competitive care), had known goal length of hospital stay (LOS) and individual case management for discharge planning.

Fransen et al† Fast-track protocol vs regular protocol: spinal vs general anaesthesia, sub-vastus versus medial parapatellar surgical approach, use of patella in-place balancing versus no patella in-place balancing , extent of soft tissue release, no tourniquet versus tourniquet use, no attachments versus standard attachments (patient controlled analgesia, wound drain, indwelling catheter), use of intraoperative LIA versus no LIA, use of ice packs versus no ice packs, Day 0 versus day 1 mobilization, prn use versus standard use of short acting opiates

* indicates significance at 0.05 level, § indicates significance according to the authors but level of significance not reported or determinable.

Table 8: Best evidence synthesis for total hip arthroplasty prognostic factors

Individual prognostic factors	Study ID, Statistical significance	Methodological quality	Overall level of evidence^	Association with early functional recovery
Age	Elings et al.* Kennedy et al. 2006 *ns* Kennedy et al. 2011 *ns* Kessler and Kafer *ns* Morri et al.* Wang et al. *ns*	High Medium Low Medium Low Medium	Conflicting	Unclear
Sex	Elings et al.* Kennedy et al. 2006* Kennedy et al. 2011 *ns* Kessler and Kafer* Morri et al.*	High Medium Low Medium Low	Conflicting	Unclear
BMI	Elings et al.* Kennedy et al. 2006 *ns* Kennedy et al. 2011 *ns* Kessler and Kafer *ns*	High Medium Low Medium	Conflicting	Unclear
ASA	Elings et al.*	High	Moderate	Yes
Charnley class	Elings et al.*	High	Moderate	Yes
Number of comorbidities	Kennedy et al. 2006 *ns* Wang et al. *ns*	Medium Medium	Moderate	No
TUG	Elings et al.* Kennedy et al. 2006*	High Medium	Limited	Yes
6MWT	Kennedy et al. 2006* Kennedy et al. 2011*	Medium Low	Limited	Yes
MBI	Wang et al.*	Medium	Limited	Yes
WOMAC	Kessler and Kafer* Salmon et al. 2001a *ns*	Medium Low	Conflicting	Unclear

Individual prognostic factors	Study ID, Statistical significance	Methodological quality	Overall level of evidence^	Association with early functional recovery
Hip strength	Wang et al. *ns*	Medium	Limited	No
Site of arthroplasty	Kennedy et al. 2006§	Medium	Limited	Yes
Incision size	Ogonda et al. *ns*	High	Limited	No
Anchorage of implant	Kessler and Kafer *ns*	Medium	Limited	No
Duration of surgery	Kessler and Kafer *ns*	Medium	Limited	No

ASA American Society of Anesthesiologists, **BMI** body mass index, **MBI** Modified Barthel Index, ***ns*** not significant, **TUG** Timed Up and Go, **WOMAC** Western Ontario and McMaster Universities Osteoarthritis Index, **6MWT** 6-minute walk test
^ the criteria used to rank levels of evidence is described in Methods section.
* indicates significance at 0.05 level, § indicates significance according to the authors but level of significance not reported or determinable.

Table 9: Best evidence synthesis for total knee arthroplasty prognostic factors

Individual prognostic factors	Study ID, Statistical significance	Methodological quality	Overall level of evidence^	Association with early functional recovery
Age	Hoogeboom et al.* Kennedy et al. 2006 *ns* Maiorano et al.* for males, females *ns* van der Sluis et al.*	High Medium Medium High	Conflicting	Unclear
Sex	Hoogeboom et al.* Kennedy et al. 2006*	High Medium	Limited	Yes
BMI	Hoogeboom et al.* Kennedy et al. 2006 *ns* Maiorano et al. *ns* van der Sluis et al. *ns*	High Medium Medium High	Conflicting	Unclear
Body weight	Carli et al.*	High	Limited	Yes
ASA	Carli et al.* van der Sluis et al.*	High High	Strong	Yes
ISAR	van der Sluis et al.*	High	Limited	Yes
Charlson index	Maiorano et al. *ns*	Medium	Limited	No
Number of comorbidities	Kennedy et al. 2006 *ns*	Medium	Limited	No
TUG	Bade et al.* van der Sluis et al.* Kennedy et al. 2006*	High High Medium	Strong	Yes
2MWT	Carli et al.*	High	Limited	Yes
6MWT	Kennedy et al. 2006*	Medium	Limited	Yes
MBI	Maiorano et al.*	Medium	Limited	Yes
DEMMI	van der Sluis et al.*	High	Limited	Yes

Individual prognostic factors	Study ID, Statistical significance	Methodological quality	Overall level of evidence^	Association with early functional recovery
Anaesthesia type - *continuous FNB* - *periarticular LIA*	Carli et al. *ns*	High	Limited	No
Anaesthesia type - *overnight FNB* - *4-day ambulatory FNB*	Ilfeld et al. *ns*	Medium	Limited	No
Morphine use	Hoogeboom et al. *ns*	High	Limited	No
Fast-track protocol[#]	Den Hertog et al.* (results reported for per protocol cohort only)	High	Limited	Yes
Fast-track protocol[†]	Fransen et al.*	Medium		
Site of arthroplasty	Kennedy et al. 2006[§]	Medium	Limited	Yes
Tourniquet time	Hoogeboom et al. *ns*	High	Limited	No
Blood loss	Hoogeboom et al. *ns*	High	Limited	No
Surgeon experience	Hoogeboom et al. *ns*	High	Limited	No

ASA American Society of Anesthesiologists, **BMI** body mass index, **DEMMI** de Morton Mobility Index, **FNB** femoral nerve block, **ISAR** Identification of Seniors At Risk, **LIA** local infiltration analgesia, **MBI** Modified Barthel Index, ***ns*** not significant, **TUG** Timed Up and Go, **2MWT** 2-minute walk test, **6MWT** 6-minute walk test,
Fast-track protocol[#] Fast-track rehabilitation versus standard rehabilitation: day of surgery mobilization versus mobilization day 2 postop, 2-hour versus 1-hour physiotherapy sessions, group therapy focusing on activities of daily living (ADL) versus individual. Fast-track group also received positive affirmation, encouraged comparison of progress with other patients (competitive care), had known goal length of hospital stay (LOS) and individual case management for discharge planning.
Fast-track protocol[†] Fast-track protocol vs regular protocol: spinal vs general anaesthesia, sub-vastus versus medial parapatellar surgical approach, use of patella in-place balancing versus no patella in-place balancing , extent of soft tissue release, no tourniquet versus tourniquet use, no attachments versus standard attachments (Patient controlled analgesia, wound drain, indwelling catheter), use of intraoperative LIA versus no LIA, use of ice packs versus no ice packs, Day 0 versus day 1 mobilization, prn use versus standard use of short acting opiates.
^ the criteria used to rank levels of evidence is described in Methods section.
*****indicates significance at 0.05 level. [§] indicates significance according to the authors but level of significance not reported or determinable.

Table 10: Outcome measures assessing inpatient functional recovery

Study	Outcome measure	Tasks assessed	ICF	Discharge criteria	LOS range, mean (days)
Bade et al. 2014	TUG*	Sit to stand Walking speed Ability to turn/change direction	A	Nil	NR
Carli et al. 2010	2MWT*	Walking speed Ability to turn/change direction	A	Nil	4 - 6 5
Carmichael et al. 2013	WOMAC**^** (pain, function and stiffness subscales)	Toilet transfers Bath transfers Donning/doffing socks Sit to stand (from bed and chair) Walking Ability to negotiate stairs Bending to floor Light and heavy domestic duties Car transfers Shopping	A	Nil	NR
Den Hertog et al. 2012	WOMAC**^** (function subscale) AKSS*	Toilet transfers Bath transfers Donning/doffing socks Sit to stand (from bed and chair) Walking Ability to negotiate stairs Bending to floor Light and heavy domestic duties Car transfers Shopping Distance walked (AKSS) Stairs (AKSS) Use of walking aid (AKSS)	A P, A, E	Patient confident for discharge Low-moderate pain No wound ooze Independent in ADL (transfers, hygiene) Independently mobile with aid >250m	NR 6.75 (FT) 13.2 (RP)
Elings et al. 2016	mILAS* (scored 0-24)	Supine to sitting Sitting to supine Sit to stand Walking	A	Medically fit mILAS $\leq$ 1 Necessary care arranged for discharge	NR

Study	Outcome measure	Tasks assessed	ICF	Discharge criteria	LOS range, mean (days)
Fransen et al. 2018	TUG* SF-12**^** KOOS**^**	Sit to stand Walking speed Ability to turn/change direction Rolling over Toilet transfers Bath transfers Donning/doffing socks Sit to stand (from bed and chair) Walking Ability to negotiate stairs Bending to floor Light and heavy domestic duties Car transfers Shopping	A P, A P, A	Able to walk independently with 2x crutches or a walker No wound problems Adequate social support	NR 3.7 (FT) 4.7 (RP)
Hoogeboom et al. 2015	mILAS* (scored 0-24)	Supine to sitting Sit to stand Walking Stair climbing	A	NR, considered functionally independent if mILAS ≤ 6	NR 2
Ilfeld et al. 2008	6MWT*	Walking speed Ability to turn/change direction	A	Adequate analgesia (NRS< 4) No IV opioids ≥ 12 hours Ability to mobilize ≥ 30m Discharge at surgeon's discretion upon fulfilment of criteria and not prior to 10.00 on POD 3	NR 3.5(Placebo) 3.6 (Ropiv)
Kennedy et al. 2006	TUG* 6MWT* WOMAC**^** (pain and function subscales)	Sit to stand (from bed and chair) Walking speed Ability to turn/change direction Toilet transfers Bath transfers Donning/doffing socks Walking Ability to negotiate stairs Bending to floor Light and heavy domestic duties Car transfers Shopping	A A P, A	NR	NR

Study	Outcome measure	Tasks assessed	ICF	Discharge criteria	LOS range, mean (days)
Kennedy et al. 2011	6MWT* LEFS**^**	Walking speed Ability to turn/change direction Rolling over Bath transfers Donning/doffing socks and shoes Walking (in home) Squatting Car transfers Light and heavy domestic duties Lifting objects (from floor) Sitting and standing for 1 hour Walking (2 blocks) Walking 1 mile Work Hobbies/sports Running on even and uneven ground Making sharp turns whilst running Hopping	A A	NR	5 - 7 NR
Kessler and Kafer 2007	WOMAC**^** (pain, function and stiffness subscales)	Toilet transfers Bath transfers Donning/doffing socks Sit to stand (from bed and chair) Walking Ability to negotiate stairs Bending to floor Light and heavy domestic duties Car transfers Shopping	P, A	NR	10 - 14 10.2
Maiorano et al. 2017	MBI*	Bed to chair transfers Ability to mobilise (+/- walking aid) Ability to negotiate stairs Dressing Grooming Feeding Bathing Toileting Bladder and bowel continence	P, A	Independent bed to chair transfers, negotiating stairs with crutches, managing personal care	NR 15.33 (females) 13.41 (males)

Study	Outcome measure	Tasks assessed	ICF	Discharge criteria	LOS range, mean (days)
Morri et al. 2016	ILAS* (scored 0-50) NB: should generate score of 0-36 for 6 tasks	Supine to sitting Sit to stand Walking Stair climbing Gait speed Type of walking aid used	A, E	NR	NR 5.6 (19 patients excluded as LOS> 7days)
Ogonda et al. 2005	mILAS* (scored 0-18) 10mWT* SCT (ascending and descending) *	Supine to sitting Sit to stand Walking Walking speed Speed and ability to negotiate stairs	A A A	NR	2 - 13 3.65 (SI) 2-22 3.68 (RI)
Salmon et al. 2001a	10mWT* 25mWT*	Walking speed	A	Not stated, implied: independent with walking aid, negotiating stairs (if required)	NR 19
Van der Sluis et al. 2017	mILAS* (scored 0-30)	Supine to sitting Sitting to supine Sit to stand Walking Stair climbing	A	Not stated, implied: considered functionally recovered once mILAS ≤ 6	NR
Wang et al. 1998	MBI*	Bed to chair transfers Ability to mobilise (+/- walking aid) Ability to negotiate stairs Dressing Grooming Feeding Bathing Toileting Bladder and bowel continence	P, A	MBI $\geq$ 90, unclear if any other criteria used	5-39 NR

* functional performance outcome measure, **^** patient-reported outcome measure, **ADL** activities of daily living, **AKSS** American Knee Society Score, **FT** Fast-Track protocol, **ICF** International Classification of Function, Disability and Health: **A** activity, **E** environmental, **P** personal, **ILAS** Iowa Level of Assistance Scale, **KOOS** Knee injury and Osteoarthritis Outcome Score, **LEFS** Lower Extremity Functional Scale, **MBI** Modified Barthel Index**, mILAS** modified Iowa Level of Assistance Scale, **NR** not reported, **NRS** numerical rating scale, **RI** routine incision, **POD** postoperative day, **Ropiv** ropivacaine group, **RP** regular protocol, **SCT** stair climbing test, **SF-12** Short form 12 health survey, **SI** small incision, **TUG** Timed Up and Go, **WOMAC** Western Ontario and McMaster Universities Osteoarthritis Index, **2MWT** 2-minute walk test, **6MWT** 6-minute walk test, **10mWT** 10-meter walk test, **25mWT** 25-meter walk test.

Discussion

This systematic review examines the evidence for patient-related and surgical prognostic factors for inpatient functional recovery following THA and TKA; determines whether inpatient functional recovery varies depending on arthroplasty site; and identifies whether inpatient functional recovery was assessed using validated outcome measures relevant to the patient's functional requirements for hospital discharge.

The level of evidence for patient-related prognostic factors and inpatient functional recovery differs between THA and TKA populations. However, associations between timed and observational performance measures of preoperative physical function or comorbidity status (ASA grade) and inpatient recovery was evident for both arthroplasty sites. Conflicting evidence exists for body mass index (BMI) and age as prognostic factors in both arthroplasty populations. The role of sex was supported by limited evidence and conflicting evidence in TKA and THA studies, respectively.

These results contrast to those published by Elings et al. (37), which (based on 2 included studies) reported moderate-level evidence for preoperative ADL status, female sex, and BMI; and conflicting evidence for increased age, as prognostic factors of delayed inpatient recovery following THA. Moderate-level evidence indicated no association for ASA grade; however, it should be noted this result was based on the findings of a single study. Greater comorbidity (Charnley class C), poorer preoperative functional performance (10-meter walk test, Timed Up and Go; TUG), and increased age were also confirmed prognostic factors of delayed functional recovery in a further study of 294 THA patients (30), which did not meet inclusion criteria in this review due to some participants undergoing revision surgery.

In summary, preoperative function has consistently been associated with early postoperative function following THA and TKA. The roles of increased comorbidity, older age, sex, and BMI must also be considered. The confirmation of these prognostic factors highlights the need for routine preoperative patient screening. Screening could be implemented conjointly with the decision to proceed to surgery, thus maximizing the preoperative window. Simple performance measures may identify patients potentially at risk of delayed recovery, providing the opportunity for preoperative medical and functional optimization, and prompt discharge planning (30,37). Prehabilitation has been demonstrated to improve preoperative function (79,80) and may successfully be implemented via telerehabilitation (81), thereby capturing patients with reduced access (82), whilst avoiding significant cost burden to both patients and healthcare organizations (83).

This review did not identify any surgical factors which were independently prognostic for postoperative functional recovery. Although the overall methodological quality of studies examining surgical factors was of a moderate to high level, sample sizes were small (40-67 participants) in 4 studies, and 3 studies did not report confidence intervals for their results. These results suggest that individual surgical factors may not significantly impact recovery and rather that ERP or Fast-track pathways, which address many aspects of the surgical pathway, are more effective in promoting early functional return. Further research is required to assess the impact of ERP using validated functional outcome measures.

Differences in the pattern of inpatient recovery following THA and TKA require further research. A single study (48) modelled the recovery pattern for both sites of arthroplasty; however, the methodological quality of this study limits the generalizability of the results. Hierarchical linear modelling was used due to the varied patient numbers and lack of standardization of postoperative time points, and several confounding factors were not accounted for. LOS was reported in 12 studies and appears to range from 2-39 days, with 9 studies stating or implying the use of discharge criteria. Due to the heterogeneity of studies with regard to the presence or type of discharge criteria used, how rigorously the discharge criteria were implemented, and when and how functional recovery was assessed, there is insufficient evidence to determine whether inpatient functional recovery differs by arthroplasty site.

Validated tools for assessing short-term postoperative function following lower limb arthroplasty are lacking (38,39). Currently there is no gold standard for evaluating functional recovery in acute hospital inpatients (39), which may explain the heterogeneity of outcome measures employed. Several PROMs including the Lower Extremity Function Scale, Knee injury and Osteoarthritis Outcome Score, and Western Ontario and McMaster Universities Osteoarthritis Index are appropriate for assessing longer-term functional outcomes as they address more advanced functional activities (38) however these activities are not achieved within the acute recovery phase and are not reflective of ADL required for hospital discharge.

Low to moderate correlations are reported between PROMs and performance measures in the early postoperative period following THA and TKA (38,41). PROMs are subjective and may be influenced by many factors (38), including perceived level of exertion (41), anxiety, and expectations regarding recovery (42); therefore performance-based measures are necessary to objectively assess actual patient function (41). However, performance measures should be clinically relevant, easily integrated into routine postoperative assessment, appropriate to the time point at which they are assessed, and implemented in a standardized manner to enable evaluation of patient outcomes across organizations. PROMs have been adopted by some National Joint Registries to record longer-term functional outcomes. Similar integration of standardized performance-based assessments could aid in generating a database of early postoperative functional outcomes, thus providing more pertinent information than LOS comparisons.

A strength of this review is the broad search undertaken with few exclusion criteria to ensure all available evidence regarding patient-related and surgical prognostic factors and inpatient functional recovery following THA and TKA was captured. Studies published in all languages were considered for inclusion. There are also several limitations. The heterogeneity of outcome measures assessed and, additionally, the modification, or varied and partial implementation of valid outcome measures (in particular the mILAS) limits the comparison of results between studies. For this reason a meta-analysis was not possible. Not all included studies published results for their early postoperative time points. Moreover, not all studies reported 95% confidence intervals, therefore the significance of some results may be questioned. None of the included studies collected data within the last 4 years, thus the potential impact of more recent surgical advances including muscle-sparing surgical approaches and robot-assisted surgery has not been assessed. For the purpose of screening, studies where joint ROM was the only postoperative outcome measure examined were excluded. Although a noted contributor, joint ROM alone is not sufficient to enable mobility or the performance of ADL.

Conclusion

Based on the findings of this review, there is strong level of evidence that comorbidity status determined by ASA grade, and preoperative functional status assessed by the TUG are prognostic factors for inpatient functional recovery following TKA. No strong level of evidence was found for patient-related prognostic factors for inpatient recovery following

THA. No surgical factors were found to be independent prognostic factors for inpatient recovery following either THA or TKA; however, limited evidence supports Fast-track protocols in the TKA population. Studies assessing inpatient functional recovery are heterogenous. Variance in methodological quality, variables examined, outcome measures, and the time points at which they are assessed makes comparison of results difficult. With shorter LOS desirable, preoperative screening is recommended to identify patients at risk of delayed inpatient recovery enabling prehabilitation, medical optimization, and early discharge planning. Valid, standardized performance measures assessing basic functional tasks would assist in objectively determining patient readiness for discharge (28), evaluating the success of ERP interventions (38), and enable benchmarking across organizations. Surgical advances in lower limb arthroplasty and their impact on inpatient functional recovery are also worthy of investigation.

CHAPTER 4: PATIENT AND SURGICAL PROGNOSTIC FACTORS FOR INPATIENT FUNCTIONAL RECOVERY FOLLOWING PRIMARY, UNILATERAL TOTAL HIP AND KNEE ARTHROPLASTY

Preface

As determined in Chapter 3, interpretation of the available evidence regarding prognostic factors for early post-operative functional recovery following lower limb arthroplasty is impeded by several factors. These include the use of inappropriate measures to assess early functional recovery, and also, non-standardised implementation of valid outcome measures. In addition, the heterogeneity of outcome measures used, and the time points at which they have been assessed, precludes the synthesis of published results. Moreover, no surgical variables have been identified as independently prognostic for post-operative functional recovery for either total hip arthroplasty (THA) or total knee arthroplasty (TKA). Thus, further research is required, to examine the associations between individual variables and inpatient functional recovery, assessed using standardised, validated functional outcome measures, appropriate to the inpatient recovery period. The impact of more recent surgical advances including muscle-sparing approaches and robot-assisted surgery also warrants investigation.

On this basis, the prospective cohort study reported in this chapter aimed to assess the relationships between potential patient and surgical prognostic factors and inpatient functional recovery following primary, unilateral THA and TKA, in a partially-standardised Enhanced Recovery private hospital setting, and using standardised, validated measures of functional recovery. In addition, the study was designed to determine whether factors associated with inpatient functional recovery differed by arthroplasty site, and also whether function assessed during the inpatient period is reflected in longer-term post-operative functional outcomes. An understanding of which factors are most strongly associated with early post-operative functional recovery may direct attention to particular components of the Enhanced Recovery Pathway (ERP), thus potentially improving ERP outcomes, in particular patient outcomes.

The prospective cohort study documented in this chapter was published in the peer-reviewed journal, Journal of Orthopaedic Surgery and Research, and is formatted according to the journal's guidelines. A copy of the published manuscript is provided in Appendix V .

Hewlett-Smith N, Pope R, Hing W, Simas V, Furness J. *Patient and surgical prognostic factors for inpatient functional recovery following THA and TKA: a prospective cohort study.* Journal of Orthopaedic Surgery and Research (2020) 15:360
https://doi.org/10.1186/s13018-020-01854-9

Abstract

Background: The introduction of enhanced recovery pathways has demonstrated both patient and organisational benefits. However, enhanced recovery pathways implemented for total hip arthroplasty (THA) and total knee arthroplasty (TKA) vary between health-care organisations, as do their measures of success, particularly patient-related outcomes. Despite inpatient functional recovery being essential for safe and timely hospital discharge, there is currently no gold standard method for its assessment, and the research undertaken to establish prognostic factors is limited. This study aimed to identify prognostic factors and subsequently develop prognostic models for inpatient functional recovery following primary, unilateral THA and TKA; identify factors associated with acute length of stay; and assess the relationships between inpatient function and longer-term functional outcomes.

Methods: Correlation and multiple regression analyses were used to determine prognostic factors for functional recovery (assessed using the modified Iowa Level of Assistance Scale on day 2 post-operatively) in a prospective cohort study of 354 patients following primary, unilateral THA or TKA.

Results: For the overall cohort and TKA group, significant prognostic factors included age, sex, pre-operative general health, pre-operative function, and use of general anaesthesia, local infiltration analgesia, and patient-controlled analgesia. In addition, arthroplasty site was a prognostic factor for the overall cohort, and surgery duration was prognostic for the TKA group. For the THA group, significant prognostic factors included pre-operative function, Risk Assessment and Prediction Tool score, and surgical approach. Several factors were associated with acute hospital length of stay. Inpatient function was positively correlated with functional outcomes assessed at 6 months post-operatively.

Conclusions: Prognostic models may facilitate the prediction of inpatient flow thus optimising organisational efficiency. Surgical prognostic factors warrant consideration as potential key elements in enhanced recovery pathways, associated with early post-operative functional recovery. Standardised measures of inpatient function serve to evaluate patient-centred outcomes and facilitate the benchmarking and improvement of enhanced recovery pathways.

Key words: Total hip arthroplasty, Total knee arthroplasty, Prognostic factors, Predictors, Inpatient function, Functional recovery

Background

The rising prevalence of osteoarthritis, in Australia and other developed countries, has seen a corresponding rise in primary total hip arthroplasty (THA) and primary total knee arthroplasty (TKA) over the past two decades (6). Since its inception in 2003, the Australian National Joint Replacement Registry has reported an increase in primary THA and TKA procedures of 108.1% and 156.2% respectively (5). The increasing burden of these elective procedures has implications for health care costs and resources (6); therefore, efficient provision of quality patient care is a priority. As such, enhanced recovery pathways (ERP) have been applied to several surgical procedures, including THA and TKA, to improve and streamline the delivery of patient care and reduce hospital length of stay (LOS).

Initially described by Kehlet (17), ERP aim to prepare patients for surgery, reduce the negative impact of surgery, and facilitate a more rapid recovery. Every step of the surgical journey, pre-operatively to post-operatively, is examined, rationalised, optimised, and standardised, resulting in a streamlined care pathway combining evidence-based clinical features with optimal organisational efficiency (13).

Although components of THA and TKA ERP have been identified, and recommendations put forward, the level of evidence supporting each of these recommendations is variable (83). Currently, no standardised guidelines apply to each ERP component, which would more readily facilitate implementation (24). The lack of defined guidelines, and the numerous components that ERP contain, mean that successful implementation requires multidisciplinary consensus at an organisational level (24). Achieving consensus to enable a standardised approach for each ERP component may prove challenging in many healthcare facilities. ERP literature reviews have suggested that future research should focus on understanding which pathway components contribute to improved recovery (18) and quantifying the impact of individual variables (23). An understanding of which variables are most associated with early post-operative functional recovery may direct attention to particular pathway components, thus further improving ERP outcomes.

A recent systematic review (85) examined the prognostic relationships between patient and surgical factors and early post-operative functional recovery assessed using validated outcome measures. The review found strong evidence that comorbidity status (determined by American Society of Anaesthesiologists, ASA grade) and pre-operative function (assessed by the Timed Up and Go test, TUG) are prognostic for inpatient functional recovery following TKA. No such evidence was found for patient-related prognostic factors for inpatient recovery following THA, and no surgical factors were found to be independently prognostic for inpatient recovery following either procedure. However, limited evidence did suggest ERP may facilitate functional recovery in the TKA population. None of the studies included in the review collected data within the last 5 years, and therefore, the potential impacts of more recent surgical advances including muscle-sparing approaches and robot-assisted surgery were not assessed.

Thus, the primary aims of this study were to examine the relationships between patient-related and surgical factors and inpatient functional recovery following THA and TKA, where functional recovery was assessed using validated functional performance measures appropriate to the early post-operative period, and, based on these findings, to develop prognostic models for inpatient functional recovery. Secondary aims were to identify patient-related, surgical, or post-operative factors associated with acute hospital LOS and to assess the relationships between functional performance measures assessed on the 2nd post-operative day (POD) and longer-term (6-month) patient-reported functional outcomes following THA and TKA.

Methods

Research Design and Setting

This prospective cohort study was conducted at The Wesley Hospital, Brisbane, an Australian privately funded, not for profit hospital. The ERP applied to this patient cohort is partially-standardised, allowing for individual preferences of surgeons and anaesthetists. Ethics approval was obtained for this study from the Uniting Care Human Research Ethics Committee (HREC no. 2016.09.187) and Bond University Human Research Ethics Committee (HREC no. 15685).

Participants

All patients undergoing elective, primary, unilateral THA and TKA between 01 May 2018 and 30 April 2019 were considered for inclusion. Potential participants were provided with information about the study (Appendix VI) for consideration prior to their attendance at pre-admission clinic, where eligibility criteria were applied and written informed consent was obtained. Patients were excluded if they were undergoing uni-compartmental, bilateral, or revision arthroplasty; not reviewed pre-operatively or unable to perform the assessments of pre-operative function; considered inappropriate to participate in the existing ERP due to multiple complex comorbidities; or identified to have significant language or cognitive barriers. A two-stage screening process was used to confirm adequate cognitive function (Appendix VII). The first stage involved verbal screening in pre-admission clinic by an occupational therapist, and a Mini-Mental State Examination (MMSE) (86) was performed for any potential participants who reported difficulty with memory or cognition. Secondly, an MMSE was undertaken for any participants whom the treating physiotherapist observed poor recall or carry-over between treatment sessions, which appeared to be limiting post-operative progression. The exclusion criteria were devised to ensure homogeneity of participants with regard to pre-operative education and surgical procedure and to exclude patients with factors reasonably considered to influence their ability to follow usual instruction or participate in the usual post-operative physiotherapy care as part of the existing ERP. All patients received usual pre-operative and post-operative care regardless of their participation in the study, with the only difference being that data pertaining to the potential prognostic factors were extracted from the medical charts of participants.

Prognostic Factors

Patient-related factors (Table 12) and potentially modifiable peri-operative and post-operative factors (Table 13) associated with the existing ERP were selected as the potential prognostic factors to be investigated.

Outcome Measures

<u>Primary outcome measure</u>

The primary outcome measure was inpatient functional recovery assessed on POD 2 using the modified Iowa Level of Assistance Scale (mILAS) (39). The mILAS (Appendix VIII) is an easily performed 6-item functional performance measure that assesses 4 activities of daily living (ADL; supine to sitting, sit to stand, walking, and negotiation of a single step), walking distance, and required mobility aid. Each item is scored 0-6, with a maximum possible total score of 36; higher scores indicate greater functional dependence. The mILAS has demonstrated validity in assessing readiness for discharge, with a statistically significant difference in median scores of 17 points observed between patients considered ready for discharge (median score 0, IQR 0-4.25) and those deemed not yet ready for discharge (median score 17, IQR 12-23) (39). The mILAS is responsive, with a minimal detectable change (MDC) of 5.8 points and large changes in scores typically evident over the course of an acute hospital admission; furthermore, it has excellent inter-rater reliability (intraclass correlation coefficient; ICC= 0.975) (39).

<u>Secondary outcome measures</u>

Timed Up and Go test, 10 metre walk test

POD 2 inpatient functional recovery was also assessed using the Timed Up and Go (TUG) test (87) and 10 metre walk test (10mWT) (88). The TUG is a reliable test of functional mobility in patients following TKA, with excellent test-retest reliability (ICC= 0.98) and a MDC of 2.27 s (89), and has been demonstrated to predict both short-term (27, 30) and long-term function following lower limb arthroplasty (71,90). The 10mWT is a reliable measure of gait speed (68). For both the TUG and 10mWT, a higher score (in seconds) indicates a slower gait speed, and each is an independent predictor of general health decline, ADL difficulty, and falls, in older community-dwelling adults (91).

Longer-term functional outcomes

Longer-term functional outcomes were assessed using patient-reported outcome measures (PROM), including the Oxford Hip Score (OHS)* (92) or Oxford Knee Score (OKS)* (93), and the EuroQol-5 Dimension visual analogue scale (EQ-5D VAS; Appendix IX) (94), each administered by telephone. The OHS and OKS are joint-specific PROM designed to assess pain behaviour and ability to perform ADL following THA and TKA, with higher scores indicating greater function (95). The OHS and OKS have undergone extensive reliability and validity testing (95) and have been used in multiple studies, to benchmark arthroplasty outcomes in the UK and Australian National Joint Replacement Registries. The minimal important changes (MIC) for assessment at the group level are 11 and 9 points for the OHS and OKS, respectively (96). For assessment of individual patients, the MIC are 8 and 7 points for the OHS and OKS, respectively (96). The distribution-based minimal detectable change (MDC90) estimates were 5 and 4 points, for the OHS and OKS, respectively (96). The English language versions, adapted for use in Australia, were used in this study, and scoring was undertaken per the respective user guides (97,98).

* Copyright prevents the reproduction of these outcome measures. Sample versions of the OHS and OKS are available at https://innovation.ox.ac.uk/wp-content/uploads/2014/09/FINAL_OHS_English_UK_SAMPLE-1.pdf https://innovation.ox.ac.uk/wp-content/uploads/2014/09/FINAL_OKS_English_UK_SAMPLE-1.pdf

The EQ-5D-5L is a widely used PROM designed to provide a simple, generic measure of health (94). The VAS component comprises a 20-cm vertical scale numbered from 0-100, 0 indicating “the worst health you can imagine” and 100 “the best health you can imagine”. Participants scoring less than 100 were asked to identify the aspect of their health responsible for generating the response. This was in order to distinguish whether the site of arthroplasty (or another aspect of general health) was the primary factor impacting their score on the EQ-5D VAS. It has previously been demonstrated that TKA functional outcomes measured using the OKS at 12 months post-operatively (34) were influenced by post-operative general physical health. As such, the EQ-5D VAS was used to assess general health as a potential contributor to functional outcomes of the participants.

Length of stay

Length of stay (LOS) was calculated as the number of nights spent in the acute hospital setting. Despite previous studies indicating that LOS is influenced by many factors other than the physical function of the patient (9,10,12,49,55,60) LOS remains a commonly used outcome measure for evaluating the success of ERP and benchmarking performance amongst healthcare organisations and thus was recorded for completeness.

Procedure

All participants underwent primary, unilateral TKA or THA procedures and received usual pre- and post-operative care in The Wesley Hospital, consistent with the existing ERP, under the direction of their treating surgeon and independent of the research. Usual physiotherapy care involved day of surgery (DOS) mobilisation (as appropriate), bidaily physiotherapy on POD 1-3 (including weekends), and daily physiotherapy on subsequent days (at the discretion of the treating physiotherapist) until time of discharge or transfer to inpatient rehabilitation. Physiotherapy incorporated range of motion and strengthening exercises, transfer practice, gait re-education, progression of mobility aids and distances walked, stairs practice, and discharge planning.

Assessments of function were undertaken at pre-determined time points (Table 11). Pre-operative function was assessed 1-4 weeks pre-operatively during a usual pre-admission appointment. Assessments of post-operative function were conducted during usual post-operative physiotherapy care, on the afternoon of POD 2, and on the morning of discharge from the orthopaedic ward. The TUG and 10mWT were assessed at each time point only if the participant was judged to be able to perform the test safely and independently (using their customary mobility aid). For both the TUG and the 10mWT, time was recorded with a stopwatch (in seconds), and participants were instructed to perform the tests as quickly as possible, without compromising their safety. At each time point, two TUG trials were completed, and the faster of the two times was recorded. For the 10mWT, only one trial was assessed at each time point. For the mILAS, participants were scored based on the same mobility aid they used when performing the TUG and 10mWT.

Table 11**:** Time points for assessment of pain and functional measures

Time point	**Assessments of pain and function**
Pre-admission clinic	- EuroQol-5Dimension Visual Analogue Scale - Oxford Hip or Knee Score - Visual analogue scale - modified Iowa Level of Assistance Scale - Timed Up and Go - 10 metre walk test
Post-operative day 2	- Visual analogue scale - modified Iowa Level of Assistance Scale - Timed Up and Go - 10 metre walk test
Day of discharge	- Visual analogue scale - modified Iowa Level of Assistance Scale - Timed Up and Go - 10 metre walk test
Six months post-operative (50% of cohort only)	- EuroQol-5Dimension Visual Analogue Scale - Oxford Hip or Knee Score

A data collection form (Appendix X) was devised to record the potential prognostic factors and the results of outcome measures for each participant. Information was entered into a secure database, and subsequently, all participants were de-identified prior to data analysis. Patient factors were recorded during a pre-operative subjective assessment; surgical and post-operative factors were extracted from the patient medical chart. Discharge date was recorded and defined as the date each participant was discharged from the acute orthopaedic ward to a suitable home environment or to inpatient rehabilitation. Patient readiness to discharge home was mutually determined by the patient and treating surgeon, with guidance from the treating physiotherapist based on ERP discharge criteria (Appendix XI) and independent of the research. Admission to inpatient rehabilitation was based on consideration of patients' post-operative medical or functional status and availability of appropriate social support, and independent of the research.

Data collection and assessment of all outcome measures were conducted by qualified physiotherapy staff. If participants were unable to perform any of the functional assessments at a particular time point (Table 11), the reason for this was recorded. Longer-term functional outcomes were assessed via telephone interview at 6 months post-operatively, for participants who comprised the first half of the study cohort.

Statistical Analysis

A recruitment target of 350 participants was planned for the study, based on power calculations conducted using G*Power software (version 3.1.9.2, 2014). This number of participants allowed sufficient numbers to ensure statistical power of at least 80% to detect small to moderate levels of association between the prognostic factors of interest and the primary outcome measure, if such existed in the underlying population, using multiple linear regression analyses and a significance level of 0.05.

All statistical analyses were conducted using SPSS (IBM, version 26, 2019). Descriptive analyses were first conducted to describe the study cohort and variables of interest and to identify missing values. Distributions of all continuous prognostic factors and outcome measures were assessed, with normality and outliers assessed via visual inspection of histograms, box plots and normal QQ plots, to inform decisions regarding the removal of outliers and approaches to statistical analysis. Independent samples *t*-tests, Mann-Whitney *U*-tests and chi-square tests were used, as appropriate based on variable types and distributions, to assess baseline differences between the two surgical groups (TKA and THA) in demographics, other prognostic factors, and outcome measures.

To enable assessment of the linearity or other form of relationships between continuous prognostic and outcome variables and so inform decision-making about whether linear regression analyses would be appropriate to use to assess prognostic relationships, simple error bar charts were developed and visually inspected. For this purpose, continuous prognostic factors were first categorised into equal intervals and then, where needed to ensure at least 10 participants in each category, two or more categories at either or both ends of the range of values for each variable were collapsed to form single categories.

Where linearity of relationships was evident, correlations between each of the ordinal or continuous prognostic factors and POD 2 mILAS were determined using Pearson's and Spearman's correlation analyses, as appropriate. Relationships between each of the nominal (dichotomous) prognostic factors and POD 2 mILAS were assessed using point biserial correlation analyses. Only prognostic factors that were significantly associated with POD 2 mILAS at the 0.1 level of statistical significance were included in subsequent multiple linear regression analyses. Nominal prognostic factors with sub-groups of less than 30 participants were also excluded from subsequent analyses due to the impacts of small sub-groups on statistical power to detect associations.

Prior to the conduct of multiple linear regression modelling, Pearson's correlation analyses were undertaken to identify collinearity among continuous prognostic factors. Similarly, point biserial correlation analyses were undertaken to determine whether any dichotomous prognostic factors were substantially correlated with the continuous prognostic factors. Pairs of factors for which the correlation analyses yielded $r > 0.7$ were identified, and in any such instances, one of the two correlated factors was removed from the subsequent regression analyses, based on pragmatic considerations which were recorded. Backward, stepwise, multiple linear regression analysis was then used to determine the combination of prognostic factors that best predicted POD 2 mILAS, with the level of statistical significance set at 0.05 for retention of any prognostic factor in the final regression model. Regression models were determined in this way for the whole cohort and separately for each of the THA and TKA cohorts.

Results

The patient and participant flow through the study is depicted in Figure 3.

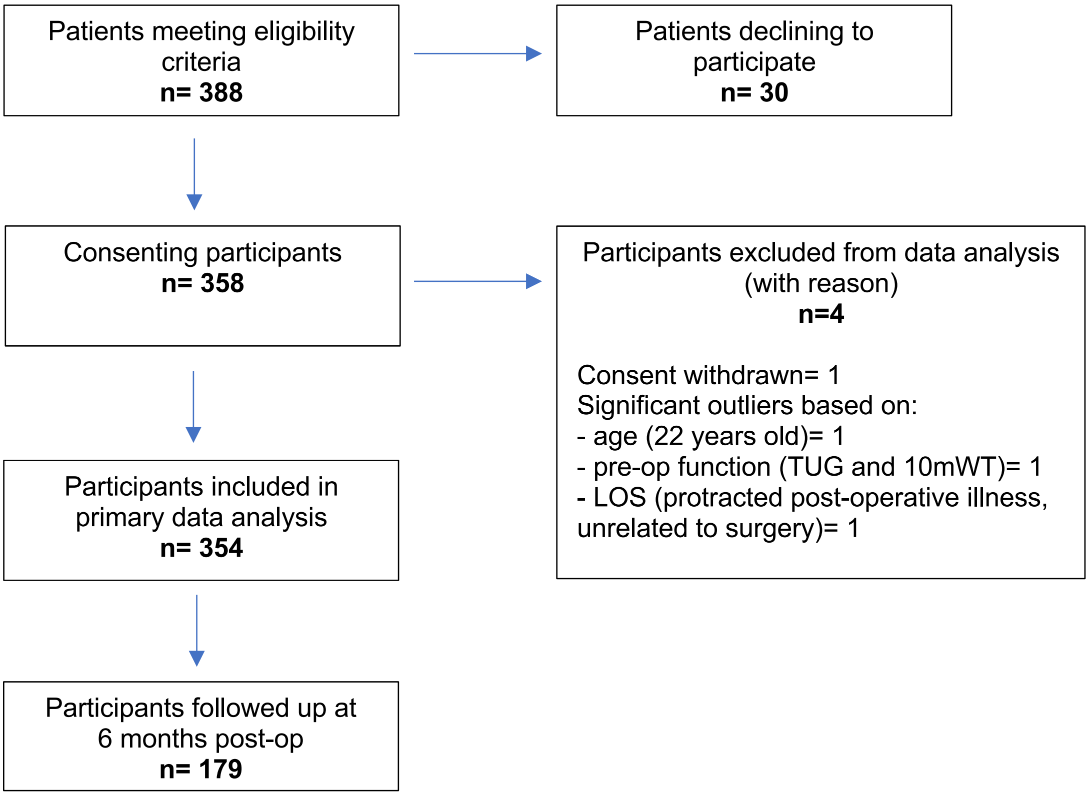

Figure 3: Study flow diagram

Descriptive statistics for patient characteristics assessed pre-operatively are presented in Table 12. Statistically significant differences existed between THA and TKA groups for mean body mass index (BMI) (p= 0.002), ASA grade distribution (p< 0.001), patient-reported pre-operative function as determined by mean OHS or OKS scores (p= 0.02), and mean Risk And Prediction Tool (RAPT) score (p= 0.03). However, with the exception of ASA grade distributions, these differences were not of a sufficient magnitude to be considered clinically important. Descriptive statistics for surgical prognostic factors extracted from medical records are presented in Table 13. A statistically significant difference was identified between THA and TKA groups only for anaesthetic method – general anaesthetic (GA) only (p= 0.04).

Table 12: Descriptive Statistics: Patient characteristics, assessed pre-operatively

Patient Characteristic		Total Cohort N= 354	TKA n= 238 (67.2%)	THA n= 116 (32.8%)	*p* value
Age (years)					
Mean (SD)		68.9 (9.2)	69.5 (8.9)	67.7 (9.9)	0.09
Sex, N (%)					
female		185(52.0%)	129 (54.2%)	56 (48.3%)	0.30
male		169 (48.0%)	109 (45.8%)	60 (51.7%)	
BMI (kg/m^2)					
Median (IQR)		30.0 (26.6, 33.6)	30.3 (27.0, 34.5)	28.4 (26.1, 31.3)	0.002*
Range		(18.1 – 48.8)	(18.1 – 48.8)	(18.9 – 45.8)	
		Missing: n= 1 (0.3%)			
ASA Grade					
N (%)	1	27 (8.2%)	12 (5.5%)	15 (13.5%)	
	2	180 (54.4%)	111 (50.5%)	69 (62.2%)	
	3	122 (36.9%)	97 (44.1%)	25 (22.5%)	<0.001*
	4	2 (0.6%)	0 (0%)	2 (1.8%)	
Median (IQR)		2 (2, 3)	2 (2, 3)	2 (2, 2)	
		Missing: n= 23 (6.5%)			
Pre-operative Hb (g/L)					
Mean (SD)		137.9 (11.8)	137.5 (11.6)	138.7 (12.1)	0.40
		Missing: n= 4 (1.1%)			
Pre-operative Pain (VAS 0-100)					
Mean (SD)		38.9 (26.3)	37.0 (26.7)	42.8 (25.0)	0.05
		Missing: n= 6 (1.7%)			
Pre-operative Function					
OKS/OHS (0-48)					
Mean (SD)		25.5 (8.0)	26.0 (8.0)	23.7 (7.9)	0.02*
		Missing n= 2 (0.6%)			
EQ-5D VAS (0-100)					
Median (IQR)		80 (70, 90)	80 (70, 90)	80 (65, 90)	0.11
Range		(10 – 100)	(10 – 100)	(18 – 100)	
		Missing: n= 4 (1.1%)			
mILAS (0-36)					
Median (IQR)		0 (0.0, 0.0)	0 (0.0, 0.0)	0 (0.0, 0.0)	0.16
Range		(0 – 11)	(0 – 11)	(0 – 11)	
TUG (sec)					
Median (IQR)		8.79 (7.41, 11.09)	8.76 (7.58, 11.05)	8.98 (7.17, 11.28)	0.56
Range		(4.39 – 30.93)	(4.97 – 29.29)	(4.39 – 30.93)	
10mWT (sec)					
Median (IQR)		7.61 (6.49, 9.40)	7.65 (6.52, 9.40)	7.58 (6.44, 9.42)	0.71
Range		(4.23 – 27.02)	(4.23 – 22.94)	(4.75 – 27.02)	
RAPT score					
Mean (SD)		9.48 (2.1)	9.3 (2.2)	9.8 (2.0)	0.03*
		Missing: n= 5 (1.4%)			

Missing data: was omitted during pre-admission assessment, or could not be extracted from patient medical chart. **ASA** American Society of Anesthesiologists, **BMI** body mass index, **EQ-5D VAS** EuroQol-5 Dimension Visual Analogue Scale, **Hb** haemaglobin, **IQR** inter-quartile range, **mILAS** modified IOWA Level of Assistance Scale, **OKS** Oxford Knee Score, **OHS** Oxford Hip Score, **RAPT** Risk Assessment and Prediction Tool, **THA** total hip arthroplasty, **TKA** total knee arthroplasty, **TUG** Timed Up and Go test, **VAS** visual analogue scale, **10mWT** Ten Metre Walk Test
*Statistical significance assessed at the 0.05 level. *p* values were derived from an independent-samples *t*-test, Mann-Whitney *U*-test or chi-square test comparing TKA and THA cohorts, as appropriate for variable type.

Table 13: Descriptive Statistics: Surgical prognostic factors

Surgical Factor	Total Cohort N= 354	TKA n= 238 (67.2%)	THA n= 116 (32.8%)	*p* value
Tourniquet duration				
(mean [SD] mins)		59.0 (21.5) n= 231 (missing n= 7)		N/A
Tourniquet pressure				
(mean [SD] mmHg)		292.5 (29.1) n= 231 (missing n= 3)		N/A
Surgical approach N (%)				
Parapatellar TKA		228 (95.8%)		
Subvastus TKA		10 (4.2%)		N/A
Posterior approach THA			71 (61.2%)	
Direct anterior approach THA			22 (19.0%)	
Direct superior approach THA			23 (19.8%)	
Robot-assisted surgery N (%)				
No	318 (89.8%)	210 (88.2%)	108 (93.1%)	0.16
Yes	36 (10.2%)	28 (11.8%)	8 (6.9%)	
Duration of surgery (min)				
Median (IQR)	79 (70, 93)	79 (71, 91)	79 (67, 100)	0.67
Range	(37-178)	(37-178)	(49-167)	
Anaesthetic method N (%)				
GA only	97 (27.4%)	57 (23.9%)	40 (34.5%)	0.04*
GA + Spinal LA	198 (55.9%)	145 (60.9%)	53 (45.7%)	0.07
Sedation + Spinal LA	55 (15.5%)	34 (14.3%)	21 (18.1%)	0.35
Other (intrathecal morphine)	4 (1.1%)	2 (0.8%)	2 (1.7%)	N/A
Initial Analgesia N (%)				
Intra-operative LIA	294 (83.1%)	214 (89.9%)	80 (69.0%)	<0.001*
PCA	76 (21.5%)	49 (20.6%)	27 (23.3%)	0.56
Oral analgesia only	27 (7.6%)	7 (2.9%)	20 (17.2%)	<0.001*
Intra-articular catheter		113 (47.5%)	N/A	
Single-shot regional block		31 (13.0%)	N/A	
Ambulatory regional block		25 (10.5%)	N/A	

Missing data: could not be extracted from patient medical chart.
GA general anaesthesia, **IQR** inter-quartile range, **LA** local anaesthesia, **LIA** local infiltration analgesia**, PCA** patient-controlled analgesia, **THA** total hip arthroplasty, **TKA** total knee arthroplasty
*Statistical significance assessed at the 0.05 level. *p* values were derived from an independent-samples *t*-test, Mann-Whitney *U*-test or chi-square test comparing TKA and THA cohorts, as appropriate for variable type.

Primary Outcome Measure

POD 2 mILAS

For the overall cohort, POD 2 mILAS scores ranged from 0 to 27, with a mean score (+/- SD) of 11.34 (+/- 6.2) points, and there were no missing values. The mean score for the THA group was 9.85 (+/- 6.0) and for the TKA group 12.06 (+/- 6.1), giving a statistically significant mean difference between the 2 groups of 2.21 points (95% CI, 0.85, 3.57), $t(352)$= 3.187, p= 0.02. Linearity was established for the relationships between POD 2 mILAS and all continuous and ordinal prognosic factors. However, following visual inspection of boxplots, three significant outliers were identified, and these participants were removed from further analysis with reasons recorded (Figure 3). The levels of association between the individual prognostic factors and POD2 mILAS scores are presented in Table 14.

Table 14**:** Correlation between individual potential prognostic factors and POD 2 mILAS scores

Patient-related factors	***r* or r_S**	***p* value**
Age	0.34	<0.001*
Pre-operative Hb	-0.19	<0.001*
RAPT score	-0.39	<0.001*
Pre-operative patient-reported function (OKS/OHS)	-0.16	<0.001*
Pre-operative function (mILAS)	0.20	<0.001*
Pre-operative function (TUG)	0.33	<0.001*
Pre-operative function (10mWT)	0.34	<0.001*
Gender (0= female, 1= male)	-0.19	<0.001*
ASA	0.17	0.002*
Pre-operative patient-reported general health (EQ-5D VAS)	-0.11	0.04*
Pre-operative pain (VAS)	0.09	0.11
BMI	0.05	0.34
Surgical factors	***r* or r_S**	***p* value**
Surgical approach (THA cohort only) (0= PA, 1= DAA or DSA)	-0.37	<0.001*
LIA use	-0.21	<0.001*
Surgery duration	-0.24	<0.001*
PCA use	0.18	0.001*
Arthroplasty site (0= THA, 1= TKA)	0.17	0.002*
Intra-articular catheter (TKA cohort only)	-0.19	0.003*
GA only	-0.13	0.02*
Sedation and spinal anaesthesia	0.09	0.09*
Robot-assisted surgery	-0.09	0.09*
Single-shot regional block (TKA cohort only)	0.08	0.21
Oral analgesia only	0.06	0.25
GA and spinal anaesthesia	0.03	0.53
Surgical approach (TKA cohort only) (1= parapatellar approach, 2= subvastus approach)	-0.04	0.54
Ambulatory regional block (TKA cohort only)	0.04	0.57
Tourniquet pressure (TKA cohort only)	-0.02	0.76
Tourniquet duration (TKA cohort only)	-0.02	0.80

ASA American Society of Anesthesiologists, **BMI** body mass index, **DAA** direct anterior approach, **DOS** day of surgery, **DSA** direct superior approach, **EQ-5D VAS** EuroQol-5 Dimension Visual Analogue Scale, **Hb** haemaglobin, **GA** general anaesthesia**, LIA** local infiltration analgesia**, mILAS** modified IOWA Level of Assistance Scale, **OKS** Oxford Knee Score, **OHS** Oxford Hip Score, **PA** posterior approach, **PCA** patient-controlled analgesia, **POD** post-operative day, **RAPT** Risk Assessment and Prediction Tool, **THA** total hip arthroplasty, **TKA** total knee arthroplasty, **TUG** Timed Up and Go test, **VAS** visual analogue scale, **10mWT** Ten Metre Walk Test
*Statistical significance assessed at the 0.1 level, *p* values were derived from Pearson's correlation, Spearman's correlation or point biserial correlation, as appropriate for variable type.

BMI, pre-operative pain (VAS), tourniquet duration, tourniquet pressure, oral analgesia only, TKA surgical approach, single-shot regional block, and regional block infusion were excluded from the subsequent regression analyses as no statistically significant association was identified between these prognostic factors and D2 mILAS scores at the 0.1 level of significance. ASA grade was not included in the regression model due to too few case numbers in ASA grades 1 and 4. Instead, Spearman's correlation analysis was used to gauge the strength of the relationship between ASA grade and POD 2 mILAS scores, and a weak but statistically significant positive correlation (r_S= 0.17(329), p= 0.002) was identified. Robot-assisted surgery was removed from TKA and THA analyses due to too few participants having undergone this type of surgery, once the cohort was split by surgical type. Pre-operative TUG time and pre-operative 10mWT time were highly correlated, *r*= 0.880, and so, the prognostic factor pre-operative 10mWT was not included in the subsequent regression analyses. This decision to remove the 10mWT rather than TUG from the subsequent regression analyses was made due to variation within the literature regarding the methodology of the 10mWT (99), and thus, its implementation in clinical practice was considered to be potentially less standardised than implementation of the TUG.

The final regression model for prediction of POD 2 mILAS scores in the overall combined TKA and THA cohort, based on significant prognostic factors, is depicted in Table 15, with R^2 of 34.7% and adjusted R^2 of 33.1%, reflecting a medium effect size (100), and with $F(8, 329)= 21.882$, $p< 0.001$. POD 2 mILAS scores (i.e. level of functional dependence of the patient) increased an average of 0.20 points for every year of age, after the other significant prognostic factors were considered (Table 15). POD 2 mILAS scores were on average 1.67 points higher for females than males and decreased an average of 0.05 points for every additional point reported on the EQ-5D VAS general health scale (Table 15). Pre-operative TUG time was a further significant prognostic factor, with POD 2 mILAS scores increasing on average 0.45 points for every additional second a patient required to complete the TUG (Table 15). Among the surgical factors, arthroplasty site was a significant prognostic factor, with POD 2 mILAS scores on average 2.21 points higher in patients who underwent a TKA rather than a THA procedure (Table 15). POD 2 mILAS scores were on average 2.07 points lower in patients who received general anaesthesia (GA) only, when compared to those who received other forms of anaesthesia (Table 15). Similarly, POD 2 mILAS scores were on average 3.02 points lower in patients who received local infiltration analgesia (LIA), when compared to those patients who did not, and POD 2 mILAS scores were on averge 2.02 points higher in patients who received post-operative analgesia via patient controlled analgesia (PCA) when compared to those patients who did not (Table 15).

Table 15**:** Final prognostic model for post-operative day 2 functional recovery (POD 2 mILAS) in overall cohort

Prognostic factors	**Unstandardized regression coefficient (*B*)**	**Standard error of the coefficient (SE_B)**	**95% CI for *B***	**Standardized coefficient (ß)**	***p* value**
Constant /Intercept	-0.906	2.550	-5.923, 4.111		0.723
Age	0.201	0.032	0.138, 0.264	0.297	<0.001
Gender (0= female, 1= male)	-1.671	0.571	-2.795, -0.547	-0.134	0.004
Pre-operative patient-reported general health (EQ-5D VAS/100)	-0.051	0.020	-0.090, -0.013	-0.126	0.009
Pre-operative function (TUG, sec)	0.453	0.094	0.269, 0.637	0.241	<0.001
Arthroplasty site (0= THA, 1= TKA)	2.223	0.631	0.982, 3.464	0.167	<0.001
Anaesthetic- use of GA only	-2.067	0.674	-3.392, -0.742	-0.148	0.002
Initial analgesia- LIA use	-3.022	0.848	-4.690, -1.355	-0.184	<0.001
Initial analgesia- PCA use	2.021	0.765	0.516, 3.526	0.134	0.009

Statistical significance assessed at the 0.05 level.
CI confidence interval, **EQ-5D VAS** EuroQol-5 Dimension Visual Analogue Scale, **GA** general anaesthesia, **LIA** local infiltration analgesia, **PCA** patient-controlled analgesia, **TUG** Timed Up and Go test, **VAS** visual analogue scale

The final regression model for prediction of POD 2 mILAS scores in the TKA group, based on significant prognostic factors, is depicted in Table 16, with R^2 of 36.4% and adjusted R^2 of 34.1%, reflecting a medium effect size (100), and with $F(8, 220)= 15.723$, $p< 0.001$. POD 2 mILAS scores increased on average 0.18 points for every year of age and were on average 1.49 points higher for females than males (Table 16). POD 2 mILAS scores decreased on average 0.09 points for every additional point reported on the EQ-5D VAS general health scale, and similarly increased an average of 0.50 points for every additional second a patient required to complete the TUG (Table 16). POD 2 mILAS scores were on average 2.07 points lower in patients who received a GA only, when compared to those who received other forms of anaesthesia (Table 16). POD 2 mILAS scores were on average 3.62 points lower in patients who received LIA, when compared to those patients who did not, and POD 2 mILAS scores were on average 2.35 points higher in patients who received post-operative analgesia via PCA when compared to those patients who did not (Table 16). POD 2 mILAS scores were also on average 0.03 points lower for every additional minute of surgical time (Table 16).

Table 16: Final prognostic model for post-operative day 2 functional recovery (POD 2 mILAS) for TKA group

Prognostic factors	**Unstandardized regression coefficient (B)**	**Standard error of the coefficient (SE_B)**	**95% CI for *B***	**Standardized coefficient (ß)**	***p* value**
Constant /Intercept	7.837	4.187	-0.415, 16.090		0.063
Age	0.184	0.042	0.101, 0.267	0.263	<0.001
Gender (0= female, 1= male)	-1.487	0.696	-2.859, -0.116	-0.120	0.034
Pre-operative patient-reported general health (EQ-5D VAS/100)	-0.087	0.024	-0.134, -0.039	-0.207	<0.001
Pre-operative function (TUG, sec)	0.503	0.114	0.279, 0.728	0.263	<0.001
Surgery duration (mins)	-0.033	0.016	-0.064, -0.002	-0.125	0.038
Anaesthetic- use of GA only	-2.066	0.858	-3.756, -0.375	-0.143	0.017
Initial analgesia- LIA use	-3.619	1.193	-5.971, -1.267	-0.179	0.003
Initial analgesia- PCA use	2.345	0.959	0.455, 4.235	0.154	0.015

Statistical significance assessed at the 0.05 level
CI confidence interval, **EQ-5D VAS** EuroQol-5 Dimension Visual Analogue Scale, **GA** general anaesthesia, **LIA** local infiltration analgesia**, PCA** patient-controlled analgesia, **TUG** Timed Up and Go test, **VAS** visual analogue scale

The final regression model for prediction of POD 2 mILAS scores in the THA group, based on significant prognostic factors, is depicted in Table 17, with R^2 of 32.4% and adjusted R^2 of 30.4%, reflecting a medium effect size (100), and with $F(3,105)= 16.742$, $p< 0.001$. POD 2 mILAS scores decreased an average of 0.94 points for every additional point scored on the RAPT, after the other significant prognostic factors were considered (Table 17). POD 2 mILAS scores increased on average 0.36 points for every additional second a patient required to complete the TUG (Table 17). THA surgical approach was a further significant prognostic factor, with POD 2 mILAS scores on average 4.67 points higher in patients who underwent THA via a posterior surgical approach when compared to other surgical approaches (direct anterior approach or direct superior approach; Table 17).

Table 17: Final prognostic model for post-operative day 2 functional recovery (POD 2 mILAS) for THA group

Prognostic factors	Unstandardized regression coefficient (B)	Standard error of the coefficient (SE_B)	95% CI for *B*	Standardized coefficient (ß)	*p* value
Constant /Intercept	17.614	3.824	10.031, 25.196		<0.001
RAPT score (/12)	-0.943	0.278	-1.493, -0.392	-0.314	0.001
Pre-operative function (TUG, sec)	0.357	0.160	0.039, 0.674	0.205	0.028
Surgical approach (0= PA, 1= DAA or DSA)	-4.671	1.016	-6.686, -2.656	-0.373	<0.001

Statistical significance assessed at the 0.05 level
CI confidence interval, **DAA** direct anterior approach, **DSA** direct superior approach, **PA** posterior approach, **RAPT** Risk Assessment and Prediction Tool, **THA** total hip arthroplasty, **TUG** Timed Up and Go test

Independent samples *t*-tests and chi-square tests revealed no statistically significant differences in age, ASA grade distributions, or measures of pre-operative, between the THA surgical approach groups - posterior approach (PA) versus direct anterior approach (DAA) or direct superior approach (DSA).

Additional analyses revealed participants who mobilised on the DOS had lower mean POD 2 mILAS scores (10.43 +/- 5.8) than those who first mobilised on POD 1 (13.64 +/- 6.5), with a statistically significant difference of 3.21 points (95% CI, 1.81, 4.61), $t(352) = 4.513$, $p < 0.001$. In the overall cohort, 49.2% experienced barriers to post-operative progress (Table 18). Participants who experienced post-operative progress barriers had higher mean POD 2 mILAS scores (14.65 +/- 5.5) than those who did not (8.13 +/- 5.0), with a statistically significant difference of 6.52 points (95% CI, -7.62, -5.42), $t(352) = -11.636$, $p < 0.001$.

Table 18: Symptoms reported in medical records as impacting post-operative progress in overall cohort

Progress barriers	N (%)
Pain	100 (28.2%)
Nausea	47 (13.3%)
Dizziness/low BP/pre-syncope	53 (15.0%)
Drowsiness/fatigue	22 (6.2%)
Delirium/impulsiveness	14 (4.0%)
Wound ooze	12 (3.4%)
Anxiety	12 (3.4%)
Constipation	12 (3.4%)
Quads inhibition	9 (2.5%)
Other (including systemically unwell or medical condition unrelated to surgery)	25 (7.1%)

Secondary Outcome Measures

POD 2 TUG and POD 2 10mWT

In the overall cohort, 75.7% and 76.3% of participants completed the POD 2 TUG and 10mWT, respectively. The reasons for non-completion of these outcome measures are as follows: 18.1% of the cohort failed to meet an appropriate level of functional independence, 2.5% were inadvertently omitted by the treating therapist, and approximately 3.0% were limited by symptoms including pain, nausea, dizziness, wound ooze, and diarrohea or were awaiting investigations. Due to the proportion of participants for whom this outcome data was missing, regression analyses were not completed for these outcome measures. However, Spearman's correlation revealed a moderate correlation between POD 2 mILAS scores and scores on each of the secondary outcome measures assessed on POD 2: POD 2 TUG $r(266)= 0.48$, $p< 0.001$, and POD 2 10mWT $r(268)= 0.39$, $p< 0.001$.

Longer term (6 months) PROMs

As planned, 6-months follow up and collection of data pertaining to longer-term outcomes were completed for 179 (50.6%) of the 354 participants included in the primary analyses. For this sub-group, the changes between baseline measures and measures assessed at 6 months post-operatively are presented in Table 19. The median increases in OHS and OKS scores for the THA and TKA sub-groups, respectively, exceeded the group MICs for these measures of 11 (OHS) and 9 points (OKS) (96) (Table 19). The OHS MIC, for individuals, of 8 points (96) was exceeded by 93.3% of the THA sub-group. Similarly, 82.9% of the TKA sub-group exceeded the OKS MIC for individuals of 7 points (96) (Table 19). An increase of only 1 point in the median change score for the EQ-5D VAS (Table 19) indicated that self-reported general health status did not differ significantly between pre-operative assessment and 6 months post-operative assessment for the participants followed up at 6 months post-operatively.

A small, negative statistically significant correlation existed between POD 2 mILAS score and OKS or OHS scores at 6 months post-operatively for the overall sub-group ($r(177)= -0.27$, $p< 0.001$), and similarly for the TKA sub-group ($r(116)= -0.19$, $p= 0.037$). A similar small, negative correlation of borderline statistical significance was found for the THA sub-group ($r(59)= -0.25$, $p= 0.052$). The correlation between POD 2 mILAS scores and EQ-5D VAS scores at 6 months post-operatively did not meet statistical significance for any of the studied cohorts.

For the THA sub-group, a moderate, positive, statistically significant correlation existed between OHS and EQ-5D VAS assessed at 6 months post-operatively ($r(59)= 0.39$, $p= 0.002$), and a non-statistically significant small, positive correlation was found between OKS and EQ-5D VAS assessed at the same time point for the TKA sub-group ($r(116)= 0.16$, $p= 0.093$). 44.1% of the overall sub-group reported health conditions unrelated to the arthroplasty undertaken during the study impacted their EQ-5D VAS assessed at 6 months post-operatively.

Table 19**:** Differences in pre-operative and longer-term (6 months post-operative) patient-reported outcome measures

Patient-reported outcome measure	**Baseline score Median (IQR) Range, n=**	**6 months post-op score Median (IQR) Range, n=**	**Change score* Median (IQR) Range, n=**	**Change score exceeded MIC At group level^ n (%) For individuals# n (%)**
OHS	22.0 (17.25, 29.0) 5-39, n= 60	46.0 (44.0, 48.0) 22-48, n= 61	22.5 (16.0, 28.75) 1-42, n= 60	60 (100%) 56 (93.3%)
OKS	25.0 (19.0, 32.0) 7-42, n= 117	43.0 (38.75, 46.0) 26-48, n= 118	16.0 (9.5, 23.0) -4.0-41.0, n= 117	117 (100%) 97 (82.9%)
EQ-5D VAS	80.0 (70.0, 90.0) 25-100, n= 178	85.0 (75.0, 90.0) 10-100, n= 179	1.0 (-5.0, 12.5) -75-50, n= 178	N/A

EQ-5D VAS: EuroQol-5 Dimension Visual Analogue Scale, **IQR** inter-quartile range, **MIC** minimal important change, **OHS** Oxford Hip Score, **OKS** Oxford Knee Score
*Change score is the difference between pre-operative baseline score and 6 months post-operative score
^For assessment at the group level, an MIC of 11 and 9 points was used for the OHS and OKS respectively (Beard et al. 2015)
#For assessment of individual patients, an MIC of 8 and 7 points was used for the OHS and OKS respectively (Beard et al. 2015)

LOS

LOS ranged from 2 to 16 days across all participants, with a median LOS of 4 days for the overall cohort, and for each of the THA and TKA groups. Statistically significant correlations were found between multiple factors and LOS (Table 20). Patient-related factors that were significantly positively correlated with LOS included age, ASA grade, and pre-operative TUG time, 10mWT time and mILAS score. Those significantly negatively correlated with LOS were pre-operative RAPT score, EQ-5D VAS, and OKS/OHS scores (Table 20). Surgical and post-operative factors significantly positively correlated with LOS included incidence of post-operative progress barriers and POD 2 mILAS, TUG and 10mWT scores (Table 20). THA (rather than TKA) surgery, DAA or DSA (rather than PA) THA, use of GA alone, combined use of GA and spinal anaesthesia, intra-operative LIA use, and DOS mobilisation were all associated with shorter LOS than their alternatives (Table 20).

Table 20: Association between individual potential prognostic factors and length of stay in overall cohort

Patient-related factors	**r_S or *U, Z* values** **IQR LOS (nights) for groups**	***p* value**
Gender (0= female, 1= male)	14685.0, -1.022 IQR female (4.0-5.0), IQR male (4.0-5.0)	0.31
Age	0.20	<0.001**
BMI	0.06	0.29
ASA	0.12	0.03*
Hb	-0.03	0.54
Living situation	0.04	0.51
RAPT score	-0.27	<0.001**
Pre-op pain (VAS)	0.08	0.15
Pre-op patient-reported general health (EQ-5D VAS)	-0.11	0.03*
Pre-op patient-reported function (OKS/OHS)	-0.18	0.001**
Pre-op function (mILAS)	0.20	<0.001**
Pre-op function (TUG)	0.26	<0.001**
Pre-op function (10mWT)	0.21	<0.001**
Surgical factors	**r_S or *U, Z* values** **IQR LOS (nights) for groups**	***p* value**
Arthroplasty site (0= THA, 1= TKA)	12065.0, -1.996 IQR THA (3.0-5.0), IQR TKA (4.0-5.0)	0.05*
Robot-assisted surgery (0= no, 1= yes)	5337.0, -0.690 IQR no (4.0-5.0), IQR yes (3.25-5.0)	0.49
GA only (0= no, 1= yes)	10172.5, -2.769 IQR no (4.0-5.0), IQR yes (3.0-5.0)	0.006**
GA and spinal anaesthesia (0= no, 1= yes)	13215.0, -2.419 IQR no (3.0-5.0), IQR yes (4.0-5.0)	0.02*
Sedation and spinal anaesthesia (0= no, 1= yes)	7972.0, -0.373 IQR no (4.0-5.0), IQR yes (4.0-5.0)	0.71
LIA use (0= no, 1= yes)	7150.0, -2.398 IQR no (4.0-5.75), IQR yes (4.0-5.0)	0.02*
PCA use (0= no, 1= yes)	9709.0, -1.122 IQR no (4.0-5.0), IQR yes (4.0-6.0)	0.26
Intra-articular catheter (TKA only) (0= no, 1= yes)	6671.0, -0.755 IQR no (4.0-5.0), IQR yes (4.0-5.0)	0.45

Single-shot regional block (TKA only) (0= no, 1= yes)	2566.5, -1.867 IQR no (4.0-5.0), IQR yes (4.0-6.0)	0.06
Ambulatory regional block (TKA only) (0= no, 1= yes)	2437.0, -0.720 IQR no (4.0-5.0), IQR yes (3.0-5.5)	0.47
Surgical approach (THA only) (0= PA, 1= DAA or DSA)	975.5, -3.645 IQR PA (4.0-5.0), IQR DAA or DSA (3.0-4.0)	<0.001**
Surgery duration	-0.03	0.52
Tourniquet duration (TKA only)	-0.02	0.94
Tourniquet pressure (TKA only)	-0.02	0.50
Post-operative factors	r_S **or** U, Z **values** **IQR LOS (nights) for groups**	p **value**
DOS mobilisation (0= no, 1= yes)	10659.0, -2.443 IQR no (4.0-6.0), IQR yes (4.0-5.0)	0.02*
Incidence of post-operative progress barriers (0= no, 1= yes)	8482.5, -7.735 IQR no (3.0-4.0), IQR yes (4.0-6.0)	<0.001**
POD 2 mILAS	0.54	<0.001**
POD 2 TUG	0.31	<0.001**
POD 2 10mWT	0.28	<0.001**

p values were derived from Spearman's correlation or Mann-Whitney *U*-test, as appropriate for variable type
ASA American Society of Anesthesiologists, **BMI** body mass index, **DAA** direct anterior approach, **DSA** direct superior approach, **DOS** day of surgery, **EQ-5D VAS** EuroQol-5 Dimension Visual Analogue Scale, **GA** general anaesthesia, **Hb** haemaglobin, **IQR** inter-quartile range, **LIA** local infiltration analgesia**, LO**S length of stay, **mILAS** modified IOWA Level of Assistance Scale, **OKS** Oxford Knee Score, **OHS** Oxford Hip Score, **PA** posterior approach, **PCA** patient-controlled analgesia, **POD** post-operative day, **RAPT** Risk Assessment and Prediction Tool, **THA** total hip arthroplasty, **TKA** total knee arthroplasty, **TUG** Timed Up and Go test, **VAS**: visual analogue scale, **10mWT** Ten Metre Walk Test
*Statistical significance $p < 0.05$ level
** Statistical significance $p < 0.01$ level

Discussion

This study assessed the strengths of the prognostic relationships between patient-related and surgical variables and inpatient functional recovery (as assessed by POD 2 mILAS score) and yielded prognostic models for inpatient functional recovery following THA and TKA. In addition, patient-related, surgical and post-operative factors associated with hospital LOS were identified, and the relationships between inpatient functional outcomes and longer-term (6-month) patient-reported functional outcomes were assessed. Overall, the findings indicate that a range of patient-related factors assessed pre-operatively as well as surgical and post-operative factors were associated with inpatient functional outcomes and with LOS following THA and TKA. In addition, longer-term functional outcomes for these patients reflected their inpatient functional outcomes. These findings address a gap in the existing evidence base, highlight the importance of assessing and optimising functional outcomes in the inpatient period, and may usefully inform the further development of ERP employed for THA and TKA.

The final prognostic models for both the overall cohort and TKA group explained approximately one third of the variance in inpatient functional recovery. Both models included as significant prognostic factors patient age, sex, pre-operative patient-reported general health, pre-operative function (TUG), and GA, LIA, and PCA use. In addition to these factors, arthroplasty site was a prognostic factor for the overall cohort, and surgery duration was prognostic for the TKA group. The final prognostic model for the THA group differed, possibly due in part to the smaller number of THA participants in the overall cohort, and included pre-operative function (TUG time), RAPT score, and surgical approach. Again, the prognostic model developed for the THA group explained approximately one third of the variance in inpatient functional recovery. Importantly, noted in each of the models was the contribution of both patient-related and surgical factors. This is the first study, to our knowledge, to identify independent, potentially modifiable surgical factors prognostic for early functional recovery following TKA or THA. The recent systematic review conducted by Hewlett-Smith et al. (85) did not find evidence that any individual surgical factors (other than site of arthroplasty) were prognostic of early functional recovery following THA or TKA.

In the prognostic models for both the overall cohort and TKA group, LIA use was associated with greater functional recovery and had the greatest prognostic value in both of these models, whereas PCA use had a negative impact on predicted POD2 mILAS scores. LIA is thought to provide effective early post-operative analgesia (without motor blockade), with less incidence of post-operative complications such as nausea, and a lower requirement for supplemental oral opioids; however, there is only low level evidence for these effects in THA (101) and TKA (102). In addition, optimal volume, composition, and site of administration of LIA have not been confirmed (84). Limiting use of PCA pumps in the routine arthroplasty population is strongly recommended due to associated functional impedance (84). Although attachments were routinely removed by POD 2 in the current study, PCA use was significantly correlated with post-operative nausea ($p < 0.001$) and dizziness ($p = 0.018$) in the overall cohort, which may explain its association with reduced functional recovery.

Less expected was the association between GA use and greater functional recovery in the overall cohort and TKA group. ERP literature has traditionally supported the use of spinal anaesthesia (13-15), although a meta-analysis of 29 studies including 10 488 patients reported no significant difference in the incidence of peri-operative complications following THA and TKA when comparing neuraxial and general anaesthesia (103). However, neuraxial methods were employed in significantly fewer patients than GA, and notably epidural rather than spinal anaesthesia was the primary mode of neuraxial anaesthesia used (103). Recently published anaesthesia consensus guidelines have reported low evidence for primary TKA and low to moderate evidence for primary THA in favour of neuraxial anaesthesia versus GA (104). However, lack of detailed information regarding the potentially wide variability in GA technique, in addition to the significant evolution in GA, and the potential influence of modern GA technique on outcomes were also acknowledged (104).

Surprisingly, longer surgery duration was prognostic of greater recovery for the TKA group. It was, however, found to have the least prognostic value in this model. As surgery duration may be influenced by multiple factors including surgeon experience, anaesthetic technique, surgical approach, surgical technique, and complexity of surgical procedure, the clinical relevance of this particular finding is unclear.

In contrast, surgical approach was strongly prognostic of greater inpatient functional recovery in the THA group, making a difference of 4.7 points on the 36-point mILAS scale. This may be due to the muscle-sparing nature of the DAA and DSA compared to the PA THA, for which inpatient functional recovery was poorer. A systematic review (105) confirms that few studies have compared THA surgical approaches using inpatient function as an outcome. Achievement of early post-operative functional goals have been reported in favour of DAA compared to PA THA (30,106,107). Recent guidelines, however, found inconclusive evidence regarding the effect of different surgical approaches on time to meet discharge criteria following THA in an enhanced recovery setting; adequately powered randomised controlled trials were recommended (23,84). Presently, this study valuably adds to the evidence available to inform practice in this area. Overall, with regard to surgical factors, our results indicate that DAA or DSA for THA, use of GA only, and LIA use were all associated with greater levels of post-operative functional recovery on POD 2, and thus warrant consideration as key ERP components.

With respect to site of arthroplasty, a statistically significant difference in POD2 mILAS scores was found in favour of the THA group; however, this may be, in part, due to the significant difference identified in ASA grade distributions between the TKA and THA groups. Although the THA group had lower pre-operative comorbidity overall (Table 1), both arthroplasty groups had a median ASA grade of 2. Additionally, the THA group had a greater proportion of patients receiving GA only (also a significant prognostic factor for POD 2 mILAS scores); however, site of arthroplasty and use of GA only were both significant independent prognostic factors within the final prognostic model for the overall cohort. Few studies have investigated site of arthroplasty as a prognostic factor for early post-operative functional outcomes. Although methodological quality limited the generalisability of the results, significantly slower functional recovery was observed in TKA patients when compared to THA patients at 1 week post-operatively (48,108).

Interestingly, several potentially modifiable patient-related factors were significantly prognostic for POD 2 mILAS scores. These include pre-operative TUG time, RAPT score, and self-reported general health status (EQ-5D VAS). TUG time was the only prognostic factor to feature in each of the final models. Findings for the overall cohort indicate that every 5-s increase in time to complete the pre-operative TUG test equates to an increase of 2.25 points in the mean predicted POD 2 mILAS score, representing poorer functional recovery. This finding is relevant particularly for patients of lower pre-operative functional status and supports the available evidence for pre-operative conditioning. The prognostic value of pre-operative TUG time, specifically, has been supported by a strong level of evidence in TKA studies, but only limited evidence in studies of THA (85). A further study, not included in the systematic review (85), also reported pre-operative TUG time in their final predictive model for functional recovery following THA (30).

Higher RAPT scores were strongly prognostic of greater POD 2 functional recovery in the THA model, such that a difference of 5 points on the RAPT would be associated with a mILAS difference of 4.7 points (equal to that associated with a change in THA surgical approach). Developed as a screening tool to predict discharge destination following THA and TKA, the RAPT score assigns values to the patient’s age, sex, pre-operative exercise tolerance, the necessity for a mobility aid or community services, and social support upon discharge (109). Although the RAPT score is primarily determined by non-modifiable factors, scoring of the exercise tolerance item and potentially the mobility aid item may be improved by optimising pre-operative function. The RAPT has only been identified in one other study as a potential predictor for early functional recovery (30) and was not included in their final prediction model.

Pre-operative patient-reported general health status had limited prognostic value in the models for both the overall cohort and TKA group. As expected, poorer pre-operative general health was associated with lower levels of post-operative functional recovery; however, a difference of 20 points on the EQ-5D VAS would be required to effect a change of 1.0 and 1.8 points in mILAS score for the overall cohort and TKA group, respectively. Furthermore, only a weak, statistically significant positive correlation was identified between ASA grade and POD 2 mILAS scores. This finding is in contrast with the strong and moderate levels of evidence for TKA and for THA, respectively, previously reported for an association between comorbidity status (ASA grade) and early post-operative functional outcomes (85).

Slower functional recovery was apparent for patients of older age and female sex in the overall cohort and TKA group. To date, two systematic reviews (37,85) have reported conflicting evidence regarding an association between age and early post-operative functional recovery following THA (37,85) and TKA (85). Similarly, conflicting evidence was found for sex (37,85) in studies of THA, whilst limited evidence supported an association between female sex and reduced early post-operative functional recovery in TKA studies (85).

Taken together, the identification of these patient-related prognostic factors supports pre-operative screening to identify patients of older age, female sex, poorer pre-operative health and functional status, and scoring lower on the RAPT as they may be less likely to achieve an accelerated recovery per many ERP. The use of these prognostic models during pre-operative screening may facilitate organisational efficiency by assisting in the prediction of patient flow. Telehealth may be a viable option for pre-operative screening in patients with reduced access to services (82) and avoids a significant cost burden to both patients and healthcare organisations (83). Prehabilitation may significantly impact pre-operative TUG time, as well as exercise tolerance, thus potentially improving RAPT score and general well-being. As per the prognostic model, improvement in pre-operative function would result in changes to predicted early post-operative functional recovery.

Few studies, to our knowledge, have linked inpatient post-operative function to longer-term outcomes. Our results are similar to Bade et al. (71) who found acute functional performance to be predictive of functional performance at 6 months post-operatively following TKA, although pre-operative functional performance was found to be a stronger predictor. The small association between POD 2 mILAS scores and patient-reported functional outcomes assessed via by OKS and OHS at 6 months post-operatively found for the overall cohort and the TKA sub-group warrants further research with larger cohorts. Inpatient function does not appear to be associated with longer-term general health. However, the EQ-5D VAS requires the respondent to rate their health "today", thus providing a very specific "snap-shot" of health status, which may be influenced by numerous factors. In addition, although a positive correlation existed between 6 months post-operative OHS and OKS scores and EQ-5D VAS assessed at the same time, 44.1% of the overall sub-group reported health conditions other than the arthroplasty undertaken during the study impacted their EQ-5D VAS. Moreover, general health ratings remained largely static pre-operatively to post-operatively despite large improvements in joint-specific functional assessments (OHS and OKS).

Inpatient functional performance was significantly correlated with LOS in the overall cohort, and similar results have been were reported by Poitras et al. (27). Higher POD 2 mILAS scores may be a useful clinical indicator of patients at risk of prolonged LOS, enabling prompt post-operative planning for patients who are recovering function more slowly than expected. Weak correlations between all patient-related factors and LOS were identified in this study. This is in contrast to previously reported strong level evidence for higher ASA grade, greater number of comorbidities, and presence of heart or lung disease as predictors of longer LOS following THA (37). THA surgical approach was the only surgical factor in this study to be moderately correlated with LOS. PA THA was associated with longer LOS than DAA or DSA. A study of 5341 THA procedures also found patients who received DAA or DSA THA had statistically significantly shorter LOS and a higher rate of discharge directly home (110).

Strengths of this study include the spectrum of patient and surgical prognostic factors and the use of standardised, validated functional performance measures which are clinically relevant, easily integrated into routine post-operative assessment, and appropriate to the time point at which they were assessed. The mILAS (39) was selected as the primary outcome measure as it incorporates tasks reflective of the ADL necessary to safely discharge home (28). Versions of the mILAS have been used in similar studies; however, its implementation is heterogenous and has thus limited the comparison of results. The study cohort is believed to be reflective of the general arthroplasty population, with few exclusion criteria implemented. To control for the potential influence of patient expectation on LOS, only patients who attended pre-admission clinic and received pre-operative education were included in the study.

There are several limitations of this study. The prognostic models are based on data from a single centre which has implemented a partially-standardised ERP. To increase generalisability, the models require internal and external validation preferably in a multi-centre study, similarly involving non-standardised ERP. POD 2 was chosen as the time point to assess functional recovery to enable comparisons with studies examining ERP outcomes where a LOS of 2 days has been reported. However, with THA and TKA being performed as ambulatory surgery in some organisations, further studies with earlier post-operative assessment time points are needed. While LIA use was identified as a significant prognostic factor, variations in site of administration, volume, and content of LIA administered were not accounted for in this study. Similarly, differences in dosage parameters, content, or duration of PCA use were not addressed; thus, further research is required to determine the impact of these variables. The impact of robotic-assisted surgery could not be fully assessed due to its application in only a small volume of the study cohort. Currently, in this facility, robotic-assisted surgery is primarily used for uni-compartmental knee arthroplasty which, to maximise homogeneity, was not included in this cohort. Due to insufficient case numbers, the role of muscle-sparing approaches for TKA was also not able to be assessed; thus, these surgical factors warrant further research. Further research is also necessary to determine cut-off points for age, pre-operative TUG time, pre-operative EQ-5D VAS, and RAPT score to further guide pre-operative screening.

Due to time constraints only the first half of the study cohort were assessed for longer-term functional outcomes. Due to the natural evolution of enhanced recovery techniques during the period of data collection, this sample may have varied slightly, with regard to surgical factors, from the remainder of the cohort. To reduce the potential for missing data, participants were not required to attend the hospital for assessment of longer-term functional outcomes. Therefore, inpatient function and longer-term functional outcomes could not be directly compared due to the variance in outcome measures assessed. However, inpatient function and longer-term functional outcomes could both be directly compared to pre-operative functional outcomes.

Validated tools for assessing short-term post-operative function following lower limb arthroplasty are lacking (38,39). In the absence of a gold standard for evaluating functional recovery in acute hospital inpatients, the mILAS (39) was used in this study. However, a 30-point version of the mILAS has recently been described and validated by Elings et al. (111) which may be of greater clinical relevance as it only assesses functional tasks. Implementation of a valid, standardised performance measure, such as this newer version of the mILAS, would assist in objective assessment of post-operative functional recovery, identification of patients at risk of prolonged LOS, and evaluation of ERP interventions (38), and also facilitate the benchmarking of patient-centred outcomes between organisations.

Conclusions

This study identified several patient-related and surgical factors prognostic for early post-operative functional recovery. Patient-related factors included in the final prognostic models for the overall cohort and TKA group were age, sex, pre-operative general health status, and pre-operative TUG time. Pre-operative TUG time and RAPT score were prognostic in the final model for the THA group. Surgical prognostic factors for the overall cohort and TKA group were use of GA only, LIA use and PCA use, with the addition of arthroplasty site in the model for the overall cohort, and surgery duration in the TKA group. Surgical approach was the only surgical prognostic factor in the model for the THA group. THA surgery was prognostic for greater functional recovery at POD 2 than TKA surgery. Several patient-related, surgical and post-operative factors were associated with acute hospital LOS. A correlation was found between functional ability at POD 2 and OKS/OHS, assessed at 6 months post-operatively. Validation of these findings is required, and assessment time points earlier in the post-operative period could be implemented. Prognostic models may facilitate the prediction of inpatient flow thus optimising organisational efficiency. In addition, surgical prognostic factors warrant consideration as potentially key ERP elements, associated with early functional recovery. Standardised functional outcome measures are needed to evaluate patient-centred ERP outcomes and to facilitate the processes of benchmarking, auditing, and improving ERP.

CHAPTER 5: DISCUSSION

This thesis investigated potential patient and surgical prognostic factors for inpatient functional recovery following primary, unilateral total hip arthroplasty (THA) and total knee arthroplasty (TKA). Initially, a narrative review described the literature pertaining to factors associated with early functional recovery and hospital length of stay (LOS) following THA and TKA. Valid methods of evaluating functional outcomes in this patient population were also considered, as these are critical to examining the relationships between potential prognostic factors and functional outcomes in the early post-operative period. Subsequently, a systematic review was conducted to identify, synthesise and analyse findings from previously published research on these relationships. Finally, informed by the findings of this systematic review, a prospective cohort study was undertaken. The primary aims of the prospective cohort study were to identify patient and surgical factors associated with inpatient functional recovery assessed on post-operative day (POD) 2 in private hospital patients who had undergone primary, unilateral THA and TKA in the context of a partially-standardised Enhanced Recovery Pathway (ERP); and based on these findings, to develop prognostic models for POD 2 functional recovery. Secondary aims were to identify factors associated with the acute LOS, and assess the relationships between inpatient function on POD 2 and longer-term functional outcomes in the studied cohort. The key findings from this program of research are discussed below.

Summary of key findings

The systematic review (Chapter 3) found strong level evidence that comorbidity status (determined by American Society of Anaesthesiologists grade; ASA) and pre-operative functional status (assessed using the Timed Up and Go; TUG test) are associated with inpatient functional recovery following TKA. Consistent with the only other systematic review undertaken in this field (37), no strong level evidence was found for an association between other patient-related factors and inpatient recovery following THA. Furthermore, no independent surgical factors were found to be associated with inpatient recovery following either THA or TKA. However, sample sizes were small in several of the included studies, and recent surgical advances including muscle-sparing surgical approaches and robot-assisted surgery were not assessed as potential prognostic factors in any of the included studies. In addition, there was insufficient evidence to determine whether inpatient functional recovery differs by arthroplasty site. The absence of a gold standard tool for assessing inpatient functional recovery, identified in Chapter 2, may partially account for the heterogeneity of outcome measures employed to assess early post-operative function. Importantly, the majority of studies included in the systematic review (Chapter 3) had not assessed early functional recovery using outcome measures appropriate to the early post-operative period, or reflective of the functional tasks used in clinical practice to assess patients' discharge readiness. Furthermore, several studies had used abbreviated versions of validated outcome measures.

The prospective cohort study (Chapter 4) determined that a number of patient-related and surgical factors were independently prognostic for inpatient recovery, which was assessed on POD 2 using the modified Iowa Level of Assistance Scale (mILAS). THA participants had a greater level of functional recovery on POD 2 when compared to TKA participants, and prognostic variables for functional outcomes differed according to arthroplasty type. In line with the findings of our systematic review, poorer pre-operative function (determined by TUG time) was associated with poorer inpatient functional recovery in each of the prognostic models. Although not included in the multiple regression analysis, ASA grade was also a significant prognostic factor for inpatient functional recovery in the study cohort. Increased age, female sex and TKA surgery were also associated with poorer inpatient functional recovery, addressing previously conflicting, and limited evidence. In contrast to the findings of the systematic review, several surgical factors were found, in the prospective cohort study (Chapter 4), to be independently prognostic of inpatient function. These surgical factors included modes of anaesthesia and analgesia delivery, and surgical approach for THA. Inpatient function was significantly correlated with LOS in the acute ward, such that patients with poorer function had longer LOS, consistent with the findings of Poitras et al (27). In addition, longer-term functional outcomes following THA and TKA (assessed using the Oxford Hip and Knee Scores six months post-operatively) were reflective of inpatient functional performance. These results are also consistent with those reported by Bade et al (71) following TKA.

Recommendations for Clinical Practice

Derived from the key findings of this program of research recommendations for clinical practice are discussed below.

- Routine pre-operative screening of ASA grade and TUG time as indicators of comorbidity and pre-operative function, respectively, should be prioritised in the TKA population to enable identification of patients potentially at risk of delayed recovery, and to provide an opportunity for pre-operative medical and functional optimisation, and early discharge planning.

- The standardised implementation of an appropriate, valid measure of early functional recovery could aid in determining patient readiness for discharge, evaluating ERP interventions, and facilitating the benchmarking of patient-centred outcomes across organisations.
- Pre-operative TUG time and pre-operative ten minute walk test (10mWT) time were highly correlated, thus suggesting that only one of these performance measures is required to assess pre-operative function. Additionally, due to variation in reported methodology of the 10mWT (99), it is recommended that the TUG be used in preference to the 10mWT for assessment of pre-operative function in this patient population.

In accordance with the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) guideline (112), further steps are required to validate the prognostic models generated in this program of research. This involves testing the prognostic capacity of the models in further prospective patient cohorts and conduction of impact analyses of the models on clinical outcomes. These additional steps must be undertaken before definitive recommendations to guide clinical decision making can be made. Thus the following points are preliminary recommendations only, based on the findings of this early stage modelling.

- Potentially modifiable patient factors, assessed pre-operatively, including TUG time, Risk Assessment and Prediction Tool (RAPT) score, and self-reported general health status (assessed via the EuroQol-5 Dimension Visual Analogue Scale; EQ-5D VAS) were significantly prognostic for functional recovery on POD 2 in the studied cohort. This finding may be relevant particularly for patients with lower pre-operative functional status or general health, and supports the available evidence for pre-operative conditioning and medical optimisation. Furthermore, early attention to discharge planning may be particularly important for these patients.
- Of the potentially modifiable patient factors mentioned above, the TUG test featured in all three of the prognostic models generated, and thus may be the best method for assessing pre-operative function in patients undergoing THA or TKA.

- Consistent with the prognostic models developed in the prospective cohort study (Chapter 4), improvement in pre-operative function may result in changes to predicted early post-operative functional recovery, and thus may also impact LOS. Thus if validated, the use of these prognostic models during pre-operative screening could also facilitate organisational efficiency by assisting in the prediction of patient flow.
- As LOS continues to be challenged, THA and TKA procedures are being performed in some facilities as ambulatory surgery (day cases). The patient factors identified in these prognostic models may be useful to assist in the preliminary identification of patients appropriate for day cases.
- The surgical factors identified warrant consideration as potential key factors impacting inpatient functional recovery.

Overall, these findings highlight the importance of assessing and optimising functional outcomes in the inpatient period, and begin to address a gap in the existing evidence base. Prospective evaluation of the prognostic capacity of these models and their impact on clinical outcomes needs to be determined before they may be applied in the further development of ERP for lower limb arthroplasty.

Strengths and limitations

A strength of this program of research was the systematic review which addressed a significant gap in the available literature. It was the first systematic review to examine patient-related prognostic factors for early post-operative functional recovery following TKA, and also the first review to examine surgical prognostic factors for early post-operative functional recovery following both THA and TKA. Further strengths were the design and methodological rigor of the prospective cohort study. This study examined a comprehensive set of potential patient-related and surgical prognostic factors, and employed standardised, validated, clinically relevant functional performance measures which are easily integrated into routine post-operative assessment. In addition, this study evaluated patient outcomes at two post-operative time points (POD 2 and 6 months post-operative). These time points were key to evaluating the association between inpatient post-operative function and longer-term functional outcomes, of which few studies have established. Furthermore, this study was undertaken in a major private hospital servicing a vast geographical area (including interstate). Few exclusion criteria were applied during participant recruitment, and thus the study cohort is believed to be reflective of the private hospital THA and TKA population in Australia. As such, its findings are an important addition to the relatively small body of available research in this area.

Nevertheless, there are several limitations to our findings. The prognostic models developed during the prospective cohort study (Chapter 4) are based on data from a single centre and in a single cohort and time period. Thus, the findings are specific to this patient population, the service and intervention provided in the context of a partially-standardised ERP. To enable generalisability, these models require external validation preferably in an international multi-centre study, incorporating both public and private hospital patient cohorts, and similarly involving non-standardised or partially-standardised ERP. Further, due to time constraints, the assessment of longer-term functional outcomes was limited to the first half of the study cohort only, and thus reduced the sample size available for the longer-term follow up element of the study.

Future research

Based on the findings and limitations of the current program of research, there are several opportunities for future research, as follows:

- Further prospective cohort studies in this, and other services, is necessary to test the prognostic capacity of this early stage modelling and its eventual impact on outcomes before they may be applied to guide decision making.
- Further research is needed to determine optimal cut off points for age, pre-operative TUG time, pre-operative EQ-5D VAS and pre-operative RAPT score, to further guide pre-operative screening and identification of those patients at risk of delayed inpatient functional recovery and requiring early attention to discharge planning.
- Further research is required to determine the impacts on early functional recovery of approaches to analgesia, including site of administration, volume and content of local infiltration analgesia; and dosage, content, or duration of use of patient-controlled analgesia.
- Further research is warranted to further investigate the impact on early functional recovery of both robot-assisted surgery for THA and TKA, and the use of muscle-sparing approaches in the TKA population.

- Further research of prognostic factors for functional recovery with earlier post-operative assessment time points is needed to enable the development of prognostic models which may be applied to patients undertaking THA or TKA as day cases.
- Further research with larger cohorts is necessary to confirm the small association found between POD 2 mILAS scores and longer-term patient-reported functional outcomes assessed by Oxford Hip and Knee Scores at six months post-operatively. In addition, due to potential variances in socio-economic status which could impact post-operative outcomes, this association must also be tested in public hospital cohorts.

Conclusions

This program of research aimed to investigate the relationships between patient-related and surgical factors and inpatient functional recovery in private hospital patients who underwent primary, unilateral THA or TKA in the context of a partially-standardised ERP. The specific objectives were achieved, as it was demonstrated that a number of patient-related and surgical factors were individually prognostic for inpatient functional outcomes, and prognostic models were subsequently developed for the study cohort. Additionally, the findings confirmed a relationship between inpatient functional outcomes and functional outcomes assessed at six months post-operatively in the studied cohort. Several clinical recommendations have been made based on the findings of this research, and further research is warranted to validate these findings, as the potential clinical applications are numerous, with potential benefits afforded to both patients and healthcare organisations.

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APPENDICES

Appendix I: Systematic Review Publication

The following article is an Open Access publication:

Hewlett-Smith N, Pope R, Furness J, Simas V, Hing W. Prognostic factors for inpatient functional recovery following total hip and knee arthroplasty: a systematic review. *Acta Orthopaedica* 2020; 91. DOI: 10.1080/17453674.2020.1744852   Licensed under CC BY-NC 4.0.

OPEN ACCESS

Acta Orthopaedica 2020; 91 (x): x–x

Prognostic factors for inpatient functional recovery following total hip and knee arthroplasty: a systematic review

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Submitted 2019-11-26. Accepted 2020-02-04.

Background and purpose — Essential for safe and timely hospital discharge, inpatient functional recovery following lower limb arthroplasty is also variable. A previous systematic review reported moderate and conflicting levels of evidence regarding patient-related predictors of inpatient recovery for primary total hip arthroplasty (THA). A systematic review of surgical prognostic factors for inpatient recovery following THA or total knee arthroplasty (TKA) is yet to be undertaken. We identified patient and surgical prognostic factors for inpatient functional recovery following THA and TKA; determined whether inpatient functional recovery varies between these procedures; and established whether validated outcome measures relevant to the patient's functional requirements for hospital discharge are routinely assessed.

Patients and methods — Critical Appraisal Skills Programme checklists assessed methodological quality, and a best-evidence synthesis approach determined the levels of evidence supporting individual prognostic factors. PubMed, CINAHL, Embase, Scopus, and PEDro databases were searched from inception to May 2019. Included studies examined patient or surgical prognostic factors and a validated measure of post-operative function within 2 weeks of primary, unilateral THA or TKA.

Results — Comorbidity status and preoperative function are supported by a strong level of evidence for TKA. For THA, no strong level of evidence was found for patient-related prognostic factors, and no surgical factors were independently prognostic for either arthroplasty site. Limited evidence supports fast-track protocols in the TKA population.

Interpretation — Preoperative screening and optimization is recommended. Assessment of Enhanced Recovery Pathways using validated outcome measures appropriate for the early postoperative period is warranted.

The International Classification of Function, Disability and Health (WHO 2013) describes the interdependent relationship among function, activity, and participation. Following lower limb arthroplasty, functional recovery is key to the independent performance of fundamental activities of daily living (ADL) such as walking, transferring in and out of bed, and climbing stairs; achieving these milestones is necessary for safe and timely hospital discharge (Shields et al. 1995, Hoogeboom et al. 2015, Poitras et al. 2015). Inability to perform basic ADL increases the patient's risk of social isolation, falls, and the need for additional resources such as rehabilitation and community services (Poitras et al. 2015).

To promote rapid recovery, multimodal Enhanced Recovery Pathways (ERP) are increasingly used for lower limb arthroplasty (Scott et al. 2013). However, the success of these pathways is primarily assessed via non patient-centric measures including morbidity and mortality, readmission rates, length of stay (LOS), and organizational economic savings (Husted 2012). Functional recovery is linked to discharge destination, longer-term functional outcomes, quality of life (Elbaz et al. 2015), patient satisfaction (Scott et al. 2012), LOS, and associated costs (Husted et al. 2008, 2010, Ibrahim et al. 2013). However, few studies have specifically examined inpatient functional recovery as an outcome following lower limb arthroplasty, using valid measures.

While studies have considered achievement of hospital-specific functional discharge criteria, these constitute neither a standardized nor a validated outcome measure. Whilst LOS may be influenced by wide-ranging factors (Husted et al. 2008, 2010, 2011, Den Hertog et al. 2012, Napier et al. 2013, Elings et al. 2016), inpatient functional recovery is commonly thought to be primarily affected by patient and surgical factors.

Surprisingly, inpatient functional recovery has been investigated by a single systematic review. Based on the results of 2

DOI 10.1080/17453674.2020.1744852

Table 1. Eligibility criteria

Criteria	Inclusion	Exclusion
Population	Humans undergoing primary elective total hip or knee arthroplasty	Bilateral total hip or knee arthroplasty Unicompartmental knee arthroplasty Hip joint re-surfacing Arthroplasty performed secondary to fracture (trauma or pathological)
Context	Australian and international studies carried out in public and private hospital settings	Studies not carried out within a public or private hospital Articles not reporting primary research
Language	All languages	Studies where language translation was not possible. However, these studies were noted for completeness, prior to exclusion
Recency of publication	All date periods preceding the search date	
Time period	Studies examining outcomes in the early postoperative period (≤ 2 weeks postoperatively)	Studies where the postoperative time point at which outcome measures were assessed is not specified or was > 2 weeks
Prognostic factors	Studies examining the relationship between 1 or more surgical or patient-related prognostic factors and functional performance or patient-reported outcome measures	Studies where the prognostic factors of interest pertained only to determining the efficacy of a treatment intervention, the specific properties of the prosthesis used or patient genetic, blood, or radiological markers
Outcomes	Studies examining at least 1 validated functional performance or patient reported outcome measure indicating postoperative functional recovery	

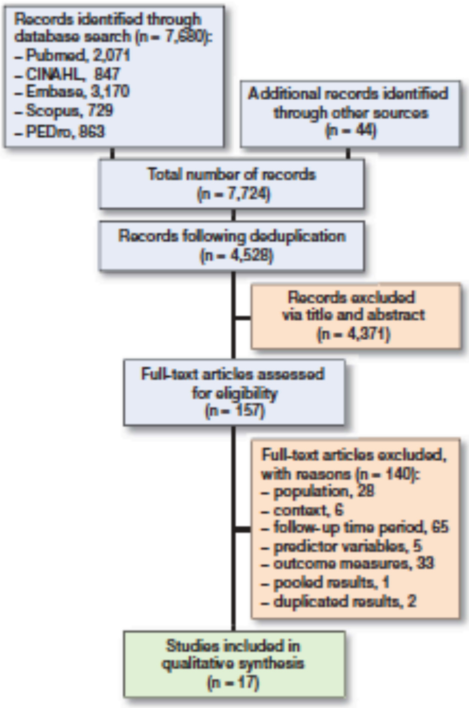
studies, Elings et al. (2015) reported moderate and conflicting levels of evidence regarding the association between patient-related factors and inpatient functional recovery. Therefore, this systematic review examines the evidence for patient and surgical prognostic factors for inpatient functional recovery following both total hip arthroplasty (THA) and total knee arthroplasty (TKA); determines whether inpatient functional recovery varies between these procedures; and identifies whether validated outcome measures relevant to the patient's functional requirements for hospital discharge are routinely assessed. The identification of surgical prognostic factors may provide an opportunity to refine ERP, whilst patient-related factors may aid in identifying those at risk of delayed recovery, enabling medical optimization, prehabilitation, and early discharge planning (Oosting et al. 2016).

Method

The systematic review protocol was registered with PROSPERO (PROSPERO Registration: CRD42019136206), and reporting is in accordance with the PRISMA statement. A comprehensive search of PubMed, CINAHL, Embase, Scopus, and PEDro databases was undertaken on May 31, 2019. The search strategy included key search terms relating to prognostic factors, hip and knee arthroplasty, and function. Subject headings specific to individual databases were utilized, and wildcards employed. No date range or language filters were applied. The PubMed/MEDLINE search strategy is presented in Appendix 1. Reference lists were also examined to capture all potentially eligible publications. Eligibility criteria (Table 1) were established and applied to the search results during initial screening of titles and abstracts. Final selection of articles based on full text review was performed independently by 2 reviewers. Differences were resolved by consensus.

Critical Appraisal Skills Programme (CASP) (2019a, 2019b, 2019c) checklists were used to address the methodological quality of the differing study designs and examine external validity, internal validity (bias), internal validity (confounding), and statistical power. To grade methodological quality, a scoring system was devised by the reviewers, and applied to each CASP checklist. Subsequently, Questions 7 and 8 of each checklist, and Question 12 of the Cohort Studies checklist were modified to elicit a "Yes," "No," or "Can't tell" response (Appendix 2). For each checklist question, a "Yes" response scored 1, and a response of "Can't tell" or "No" scored 0; for questions involving a 2-part answer, parts (a) and (b) were scored separately. Using this system, the CASP checklists for Randomized Controlled Trials, Case Control Studies, and Cohort Studies had a maximum possible score of 11, 12, and 14, respectively. Scores were converted to a percentage and ranges were determined (by the reviewers) to reflect methodological quality as follows: < 30% low quality, 31–65% medium quality, and > 65% high quality. Studies were independently appraised by 2 reviewers, and Cohen's Kappa (κ) (Cohen 1960) assessed level of agreement; differences were resolved by discussion and consensus.

Extracted data was tabulated, including: study design, context, sample size, demographics, arthroplasty site, prognostic factors, validated measures of postoperative functional recovery, and the time points at which these were assessed. Meta-analysis was not possible due to the methodological hetero-



PRISMA flow diagram.

geneity of included studies, therefore a best evidence synthesis approach was employed. Evidence levels were ranked as follows: strong evidence is provided by ≥ 2 studies with low risk of bias and by generally consistent findings in all studies (≥ 75% of the studies reported consistent findings); moderate evidence is provided by 1 low risk of bias study and ≥ 2 moderate/high risk of bias studies or by ≥ 2 moderate/ high risk of bias studies and by generally consistent findings in all studies (≥ 75%); limited evidence is provided by ≥ 1 moderate/high risk of bias studies or 1 low risk of bias study and by generally consistent findings (≥ 75%); conflicting evidence is provided by conflicting findings (< 75% of the studies reported consistent findings) (Eijgenraam et al. 2018).

Results

The search identified 7,724 records and, following screening, 17 studies were included (Figure). These incorporated 1,171 THA and 1,662 TKA procedures. 8 studies investigated THA, 8 TKA, and 1 both procedures (Table 2, see Supplementary data). 12 studies examined patient-related factors (Table 3, see Supplementary data) and 9 studies investigated surgical factors (Table 4, see Supplementary data). Numerous tools evaluated comorbidity status and preoperative function. Postoperative functional recovery was assessed via 14 different validated functional performance and patient-reported outcome measures (PROM). Assessment time points varied significantly between studies within the 2-week postoperative period.

Critical appraisal results are presented in Appendix 3; 7 studies were rated as high methodological quality, 7 as medium quality, and 3 as low quality. There was strong level of agreement between the two reviewers' judgements (κ = 0.944, $p < 0.001$). The best-evidence synthesis for prognostic factors for early functional recovery following THA and TKA is presented in Tables 5 and 6 respectively (see Supplementary data).

The heterogeneity of outcome measures employed in the included studies is presented in Appendix 4. Only 7 studies utilized objective outcome measures that assess key functional tasks representative of ADL required for discharge. The Modified Barthel Index (MBI; Shah et al. 1989), Iowa Level of Assistance Scale (ILAS; Shields et al. 1995) and modified Iowa Level of Assistance Scale (mILAS; Oldmeadow et al. 2006) each assess tasks including bed or chair transfers, ambulation, stair climbing, and the amount of assistance required for their achievement. However, the mILAS was further modified (from that published by Oldmeadow et al. 2006) in 2 studies (Elings et al. 2016, van der Sluis et al. 2017) and only partially implemented in all 4 studies where it was assessed, potentially compromising its validity, the generalizability of results and also the ability to compare outcomes between studies. Morri et al. (2016) describe the scoring method for the ILAS inaccurately, casting doubt on the validity of its implementation.

Discussion

This systematic review examines the evidence for patient-related and surgical prognostic factors for inpatient functional recovery following THA and TKA; determines whether inpatient functional recovery varies depending on arthroplasty site; and identifies whether inpatient functional recovery was assessed using validated outcome measures relevant to the patient's functional requirements for hospital discharge.

The level of evidence for patient-related prognostic factors and inpatient functional recovery differs between THA and TKA populations. However, associations between timed and observational performance measures of preoperative physical function or comorbidity status (ASA grade) and inpatient recovery was evident for both arthroplasty sites. Conflicting evidence exists for body mass index (BMI) and age as prognostic factors in both arthroplasty populations. The role of sex was supported by limited evidence and conflicting evidence in TKA and THA studies, respectively.

These results contrast to those published by Elings et al. (2015), which (based on 2 included studies) reported moderate-level evidence for preoperative ADL status, female sex, and BMI; and conflicting evidence for increased age, as prognostic factors of delayed inpatient recovery following THA. Moderate-level evidence indicated no association for ASA grade; however, it should be noted this result was based on the findings of a single study. Greater comorbidity (Charnley class C), poorer preoperative functional performance (10-meter walk test, Timed Up and Go [TUG]), and increased age were also confirmed prognostic factors of delayed functional recovery in a further study of 294 THA patients (Oosting et al. 2016), which did not meet inclusion criteria in this review due to some participants undergoing revision surgery.

In summary, preoperative function has consistently been associated with early postoperative function following THA and TKA. The roles of increased comorbidity, older age, sex, and BMI must also be considered. The confirmation of these prognostic factors highlights the need for routine preoperative patient screening. Screening could be implemented conjointly with the decision to proceed to surgery, thus maximizing the preoperative window. Simple performance measures may identify patients potentially at risk of delayed recovery, providing the opportunity for preoperative medical and functional optimization, and prompt discharge planning (Elings et al. 2015, Oosting et al. 2016). Prehabilitation has been demonstrated to improve preoperative function (Swank et al. 2011, Clode et al. 2018) and may successfully be implemented via telerehabilitation (Doiron-Cadrin et al. 2019), thereby capturing patients with reduced access (Westby et al. 2010), whilst avoiding significant cost burden to both patients and healthcare organizations (Fusco and Turchetti 2016).

This review did not identify any surgical factors that were independently prognostic for postoperative functional recovery. Although the overall methodological quality of studies examining surgical factors was of a moderate to high level, sample sizes were small (40–67 participants) in 4 studies, and 3 studies did not report confidence intervals for their results. These results suggest that individual surgical factors may not significantly impact recovery and rather that ERP or Fast-track pathways, which address many aspects of the surgical pathway, are more effective in promoting early functional return. Further research is required to assess the impact of ERP using validated functional outcome measures.

Differences in the pattern of inpatient recovery following THA and TKA require further research. A single study (Kennedy et al. 2006) modelled the recovery pattern for both sites of arthroplasty; however, the methodological quality of this study limits the generalizability of the results. Hierarchical linear modelling was used due to the varied patient numbers and lack of standardization of postoperative time points, and several confounding factors were not accounted for. LOS was reported in 12 studies and appears to range from 2 to 39 days, with 9 studies stating or implying the use of discharge criteria. Due to the heterogeneity of studies with regard to the presence or type of discharge criteria used, how rigorously the discharge criteria were implemented, and when and how functional recovery was assessed, there is insufficient evidence to determine whether inpatient functional recovery differs by arthroplasty site.

Validated tools for assessing short-term postoperative function following lower limb arthroplasty are lacking (Kimmel et al. 2016, Poitras et al. 2016). Currently there is no gold standard for evaluating functional recovery in acute hospital inpatients (Kimmel et al. 2016), which may explain the heterogeneity of outcome measures employed. Several PROMs including the Lower Extremity Function Scale, Knee injury and Osteoarthritis Outcome Score, and WOMAC are appropriate for assessing longer-term functional outcomes as they address more advanced functional activities (Poitras et al. 2016) however these activities are not achieved within the acute recovery phase and are not reflective of ADL required for hospital discharge.

Low to moderate correlations are reported between PROMs and performance measures in the early postoperative period following THA and TKA (Mizner et al. 2011, Poitras et al. 2016). PROMs are subjective and may be influenced by many factors (Poitras et al. 2016), including perceived level of exertion (Mizner at al. 2011), anxiety, and expectations regarding recovery (Salmon et al. 2001b); therefore performance-based measures are necessary to objectively assess actual patient function (Mizner et al. 2011). However, performance measures should be clinically relevant, easily integrated into routine postoperative assessment, appropriate to the time point at which they are assessed, and implemented in a standardized manner to enable evaluation of patient outcomes across organizations. PROMs have been adopted by some National Joint Registries to record longer-term functional outcomes. Similar integration of standardized performance-based assessments could aid in generating a database of early postoperative functional outcomes, thus providing more pertinent information than LOS comparisons.

A strength of this review is the broad search undertaken with few exclusion criteria to ensure all available evidence regarding patient-related and surgical prognostic factors and inpatient functional recovery following THA and TKA was captured. Studies published in all languages were considered for inclusion. There are also several limitations. The heterogeneity of outcome measures assessed and, additionally, the modification, or varied and partial implementation of valid outcome measures (in particular the mILAS) limits the comparison of results between studies. For this reason a meta-analysis was not possible. Not all included studies published results for their early postoperative time points. Moreover, not all studies reported 95% confidence intervals, therefore the significance of some results may be questioned. None of the included studies collected data within the last 4 years, thus the potential impact of more recent surgical advances including muscle-sparing surgical approaches and robotic-assisted surgery has not been assessed. For the purpose of screening, studies where joint ROM was the only postoperative outcome measure examined were excluded. Although a noted contributor, joint ROM alone is not sufficient to enable mobility or the performance of ADL.

Conclusion

Based on the findings of this review, there is strong level of evidence that comorbidity status determined by ASA grade, and preoperative functional status assessed by the TUG are prognostic factors for inpatient functional recovery following TKA. No strong level of evidence was found for patient-related prognostic factors for inpatient recovery following THA. No surgical factors were found to be independent prognostic factors for inpatient recovery following either THA or TKA; however, limited evidence supports Fast-track protocols in the TKA population. Studies assessing inpatient functional recovery are heterogeneous. Variance in methodological quality, variables examined, outcome measures, and the time points at which they are assessed makes comparison of results difficult. With shorter LOS desirable, preoperative screening is recommended to identify patients at risk of delayed inpatient recovery enabling prehabilitation, medical optimization, and early discharge planning. Valid, standardized performance measures assessing basic functional tasks would assist in objectively determining patient readiness for discharge (Shields et al. 1995), evaluating the success of ERP interventions (Poitras et al. 2016), and enable benchmarking across organizations. Surgical advances in lower limb arthroplasty and their impact on inpatient functional recovery are also worthy of investigation.

Funding and potential conflicts of interest

This research was supported by an Australian Government Research Training Program Scholarship.

Each author certifies that he or she has no commercial associations that might pose a conflict of interest in connection with the submitted article.

Data statement

N H-S is registered with the data repository Open Science Framework.

Supplementary data

Tables 2–6 and Appendices 1–4 are available as supplementary data in the online version of this article, http://dx.doi.org/10.1080/17453674.2020.1744852

Conception/planning: NH-S, RP, WH. Initial screening: NH-S. Full text review: NH-S, VS. Data extraction: NH-S, VS. Critical appraisal: NH-S, VS. Best evidence synthesis: NH-S, JF. Results: NH-S, RP, JF. Discussion/conclusion: NH-S, RP, JF, WH. Formatting/editing: NH-S, RP, JF, WH.

The authors wish to acknowledge Ross Ferguson (The Wesley Hospital) and David Honeyman (Bond University) for their support and contributions.

Acta thanks Petri Virolainen and André Stark for help with peer review of this study.

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Appendix II: Systematic Review Search Stategy For PubMed/MEDLINE

Database	Search strategy
PubMed/MEDLINE Searching all fields	(predict* **OR** prognos* **OR** "Forecasting"[Mesh]) **AND** ((arthroplast* **OR** replace* **OR** prosthes*) **AND** (lower limb **OR** hip **OR** knee) **OR** ("Arthroplasty, Replacement, Hip"[Mesh] **OR** "Arthroplasty, Replacement, Knee"[Mesh])) **AND** (function*)

Appendix III: CASP Checklist Modification To Enable Scoring For Methodological Quality

CASP checklist questions were re-worded as follows:
Question 7 of CASP checklists (Case Control Study, Cohort Study and Randomised Controlled Trial), 'What are the results of this study?' was adjusted to read 'Was the treatment effect size worthwhile for the context and population in which it is intended it would be applied?'.

Question 8 of CASP checklists (Case Control Study, Cohort Study and Randomised Controlled Trial) 'How precise are the results?' was altered to read 'Did the confidence limits around the treatment effect indicate that the minimum expected effect would be worthwhile in this context and population?'.

Question 12 of CASP checklist (Cohort Study) 'What are the implications of this study for practice?' was modified to read 'Are there implications of this study for practice?

Appendix IV: CASP Checklist Scores For Individual Studies

Study	Checklist	Q1	Q2	Q3	Q4	Q5		Q6		Q7	Q8	Q9	Q10	Q11	Q12	Total score	Percentage
Bade et al, 2014	Cohort	1	1	1	1	1	1	1	1	1	1	1	0	1	1	13 /14	93
Elings et al, 2016	Cohort	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14 /14	100
Hoogeboom et al, 2015	Cohort	1	1	1	1	0	0	1	1	1	1	1	1	0	1	11 /14	79
Kennedy et al, 2006a	Cohort	1	1	0	1	0	0	1	1	0	0	0	0	0	0	5 /14	38
Kennedy et al, 2011	Cohort	1	0	0	1	0	0	0	1	0	1	0	0	0	0	4 /14	29
Kessler and Kafer, 2007	Cohort	1	1	0	1	0	0	1	1	0	1	0	0	0	0	6 /14	43
Maiorano et al, 2017	Cohort	1	0	1	1	0	0	1	0	0	1	0	0	0	0	5 /14	38
Morri et al, 2016	Cohort	1	0	0	0	0	0	0	0	1	1	0	0	1	0	4 /14	29
Salmon et al, 2001a	Cohort	1	0	0	0	0	0	1	1	0	0	0	0	0	0	3 /14	21
Van der Sluis et al, 2017	Cohort	1	1	1	1	1	1	1	1	0	1	1	1	1	1	13 /14	93
Wang et al, 1998	Cohort	1	1	0	1	0	0	0	1	0	1	0	0	1	1	7 /14	50
Carli et al, 2010	RCT	1	1	1	1	1		1		1	1	1	1	1	1	11 /11	100
Carmichael et al, 2018	RCT	1	1	1	1	1		1		0	0	0	1	0	N/A	7 /11	64
Fransen et al, 2018	RCT	1	1	1	0	1		1		0	0	0	0	1	N/A	6 /11	55
Ilfeld et al, 2001	RCT	1	1	1	1	0		1		1	1	0	0	0	N/A	7 /11	64
Ogonda et al, 2005	RCT	1	1	1	1	1		1		1	0	0	1	1	N/A	9 /11	82
Den Hertog et al, 2012	Case control	1	1	1	1	1		1	1	0	0	0	1	1	N/A	9 /12	75

Appendix V: Prospective Cohort Study Publication

The following article is an Open Access publication:

Hewlett-Smith N, Pope R, Hing W, Simas V, Furness J. *Patient and surgical prognostic factors for inpatient functional recovery following THA and TKA: a prospective cohort study.* Journal of Orthopaedic Surgery and Research (2020) 15:360
https://doi.org/10.1186/s13018-020-01854-9

Hewlett-Smith *et al. Journal of Orthopaedic Surgery and Research* (2020) 15:360
https://doi.org/10.1186/s13018-020-01854-9

Journal of Orthopaedic Surgery and Research

RESEARCH ARTICLE **Open Access**

Patient and surgical prognostic factors for inpatient functional recovery following THA and TKA: a prospective cohort study

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Abstract

Background: The introduction of enhanced recovery pathways has demonstrated both patient and organisational benefits. However, enhanced recovery pathways implemented for total hip arthroplasty (THA) and total knee arthroplasty (TKA) vary between health-care organisations, as do their measures of success, particularly patient-related outcomes. Despite inpatient functional recovery being essential for safe and timely hospital discharge, there is currently no gold standard method for its assessment, and the research undertaken to establish prognostic factors is limited. This study aimed to identify prognostic factors and subsequently develop prognostic models for inpatient functional recovery following primary, unilateral THA and TKA; identify factors associated with acute length of stay; and assess the relationships between inpatient function and longer-term functional outcomes.

Methods: Correlation and multiple regression analyses were used to determine prognostic factors for functional recovery (assessed using the modified Iowa Level of Assistance Scale on day 2 post-operatively) in a prospective cohort study of 354 patients following primary, unilateral THA or TKA.

Results: For the overall cohort and TKA group, significant prognostic factors included age, sex, pre-operative general health, pre-operative function, and use of general anaesthesia, local infiltration analgesia, and patient-controlled analgesia. In addition, arthroplasty site was a prognostic factor for the overall cohort, and surgery duration was prognostic for the TKA group. For the THA group, significant prognostic factors included pre-operative function, Risk Assessment and Prediction Tool score, and surgical approach. Several factors were associated with acute hospital length of stay. Inpatient function was positively correlated with functional outcomes assessed at 6 months post-operatively.

Conclusions: Prognostic models may facilitate the prediction of inpatient flow thus optimising organisational efficiency. Surgical prognostic factors warrant consideration as potential key elements in enhanced recovery pathways, associated with early post-operative functional recovery. Standardised measures of inpatient function serve to evaluate patient-centred outcomes and facilitate the benchmarking and improvement of enhanced recovery pathways.

Keywords: Total hip arthroplasty, Total knee arthroplasty, Prognostic factors, Predictors, Inpatient function, Functional recovery

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Background

The rising prevalence of osteoarthritis, in Australia and other developed countries, has seen a corresponding rise in primary total hip arthroplasty (THA) and primary total knee arthroplasty (TKA) over the past two decades [1]. Since its inception in 2003, the Australian National Joint Replacement Registry has reported an increase in primary THA and TKA procedures of 108.1% and 156.2% respectively [2]. The increasing burden of these elective procedures has implications for health care costs and resources [1]; therefore, efficient provision of quality patient care is a priority. As such, enhanced recovery pathways (ERP) have been applied to several surgical procedures, including THA and TKA, to improve and streamline the delivery of patient care and reduce hospital length of stay (LOS).

Initially described by Kehlet [3], ERP aim to prepare patients for surgery, reduce the negative impact of surgery, and facilitate a more rapid recovery. Every step of the surgical journey, pre-operatively to post-operatively, is examined, rationalised, optimised, and standardised, resulting in a streamlined care pathway combining evidence-based clinical features with optimal organisational efficiency [4].

Although components of THA and TKA ERP have been identified, and recommendations put forward, the level of evidence supporting each of these recommendations is variable [5]. Currently, no standardised guidelines apply to each ERP component, which would more readily facilitate implementation [6]. The lack of defined guidelines, and the numerous components that ERP contain, means that successful implementation requires multidisciplinary consensus at an organisational level [6]. Achieving consensus to enable a standardised approach for each ERP component may prove challenging in many healthcare facilities. ERP literature reviews have suggested that future research should focus on understanding which pathway components contribute to improved recovery [7] and quantifying the impact of individual variables [8]. An understanding of which variables are most associated with early post-operative functional recovery may direct attention to particular pathway components, thus further improving ERP outcomes.

A recent systematic review [9] examined the prognostic relationships between patient and surgical factors and early post-operative functional recovery assessed using validated outcome measures. The review found strong evidence that comorbidity status (determined by American Society of Anaesthesiologists, ASA grade) and pre-operative function (assessed by the Timed Up and Go test, TUG) are prognostic for inpatient functional recovery following TKA. No such evidence was found for patient-related prognostic factors for inpatient recovery following THA, and no surgical factors were found to be independently prognostic for inpatient recovery following either procedure. However, limited evidence did suggest ERP may facilitate functional recovery in the TKA population. None of the studies included in the review collected data within the last 5 years, and therefore, the potential impacts of more recent surgical advances including muscle-sparing approaches and robot-assisted surgery were not assessed.

Thus, the primary aims of this study were to examine the relationships between patient-related and surgical factors and inpatient functional recovery following THA and TKA, where functional recovery was assessed using validated functional performance measures appropriate to the early post-operative period, and, based on these findings, to develop prognostic models for inpatient functional recovery. Secondary aims were to identify patient-related, surgical, or post-operative factors associated with acute hospital LOS and to assess the relationships between functional performance measures assessed on the 2nd post-operative day (POD) and longer-term (6-month) patient-reported functional outcomes following THA and TKA.

Methods

Research design and setting

This prospective cohort study was conducted at The Wesley Hospital, Brisbane, an Australian privately funded, not for profit hospital. The ERP applied to this patient cohort is partially standardised, allowing for individual preferences of surgeons and anaesthetists. Ethics approval was obtained for this study from the Uniting Care Human Research Ethics Committee (HREC no. 2016.09.187) and Bond University Human Research Ethics Committee (HREC no. 15685).

Participants

All patients undergoing elective, primary, unilateral THA and TKA between 1 May 2018 and 30 April 2019 were considered for inclusion. Potential participants were provided with information about the study for consideration prior to their attendance at pre-admission clinic, where eligibility criteria were applied and written informed consent was obtained. Patients were excluded if they were undergoing uni-compartmental, bilateral, or revision arthroplasty; not reviewed pre-operatively or unable to perform the assessments of pre-operative function; considered inappropriate to participate in the existing ERP due to multiple complex comorbidities; or identified to have significant language or cognitive barriers. A two-stage screening process was used to confirm adequate cognitive function (Appendix 1). The first stage involved verbal screening in the pre-admission clinic by an occupational therapist, and a Mini-Mental State Examination (MMSE) [10] was performed for any potential participants who reported difficulty with memory or cognition. Secondly, an MMSE was undertaken for any participants whom the treating physiotherapist observed poor recall or carry-over between treatment sessions, which appeared to be limiting post-operative progression. The exclusion criteria were devised to ensure homogeneity of participants with regard to pre-operative education and surgical procedure and to exclude patients with factors reasonably considered to influence their ability to follow usual instruction or participate in the usual post-operative physiotherapy care as part of the existing ERP. All patients received usual pre-operative and post-operative care regardless of their participation in the study, with the only difference being that data pertaining to the potential prognostic factors were extracted from the medical charts of participants.

Prognostic factors

Patient-related factors (Table 2) and potentially modifiable peri-operative and post-operative factors (Table 3) associated with the existing ERP were selected as the potential prognostic factors to be investigated.

Outcome measures

Primary outcome measure

The primary outcome measure was inpatient functional recovery assessed on POD 2 using the modified Iowa Level of Assistance Scale (mILAS) [11]. The mILAS (Appendix 2) is an easily performed 6-item functional performance measure that assesses 4 activities of daily living (ADL; supine to sitting, sit to stand, walking, and negotiation of a single step), walking distance, and required mobility aid. Each item is scored 0–6, with a maximum possible total score of 36; higher scores indicate greater functional dependence. The mILAS has demonstrated validity in assessing readiness for discharge, with a statistically significant difference in median scores of 17 points observed between patients considered ready for discharge (median score 0, IQR 0–4.25) and those deemed not yet ready for discharge (median score 17, IQR 12–23) [11]. The mILAS is responsive, with a minimal detectable change (MDC) of 5.8 points and large changes in scores typically evident over the course of an acute hospital admission; furthermore, it has excellent inter-rater reliability (intraclass correlation coefficient; ICC = 0.975) [11].

Secondary outcome measures

Timed Up and Go test, 10-metre walk test POD 2 inpatient functional recovery was also assessed using the Timed Up and Go (TUG) test [12] and 10-metre walk test (10mWT) [13]. The TUG is a reliable test of functional mobility in patients following TKA, with excellent test-retest reliability (ICC = 0.98) and a MDC of 2.27 s [14], and has been demonstrated to predict both short-term [15, 16] and long-term function following lower limb arthroplasty [17, 18]. The 10mWT is a reliable measure of gait speed [19]. For both the TUG and 10mWT, a higher score (in seconds) indicates a slower gait speed, and each is an independent predictor of general health decline, ADL difficulty, and falls, in older community-dwelling adults [20].

Longer-term functional outcomes Longer-term functional outcomes were assessed using patient-reported outcome measures (PROM), including the Oxford Hip Score (OHS) [21] or Oxford Knee Score (OKS) [22], and the EuroQol-5 Dimension visual analogue scale (EQ-5D VAS) [23], each administered by telephone. The OHS and OKS are joint-specific PROM designed to assess pain behaviour and ability to perform ADL following THA and TKA, with higher scores indicating greater function [24]. The OHS and OKS have undergone extensive reliability and validity testing [24] and have been used in multiple studies, to benchmark arthroplasty outcomes in the UK and Australian National Joint Replacement Registries. The minimal important changes (MIC) for assessment at the group level are 11 and 9 points for the OHS and OKS, respectively [25]. For assessment of individual patients, the MIC are 8 and 7 points for the OHS and OKS, respectively [25]. The distribution-based minimal detectable change (MDC90) estimates were 5 and 4 points, for the OHS and OKS, respectively [25]. The English language versions, adapted for use in Australia, were used in this study, and scoring was undertaken per the respective user guides [26, 27].

The EQ-5D-5L is a widely used PROM designed to provide a simple, generic measure of health [23]. The VAS component comprises a 20-cm vertical scale numbered from 0 to 100, 0 indicating "the worst health you can imagine" and 100 "the best health you can imagine". Participants scoring less than 100 were asked to identify the aspect of their health responsible for generating the response. This was in order to distinguish whether the site of arthroplasty (or another aspect of general health) was the primary factor impacting their score on the EQ-5D VAS. It has previously been demonstrated that TKA functional outcomes measured using the OKS at 12 months post-operatively [28] were influenced by post-operative general physical health. As such, the EQ-5D VAS was used to assess general health as a potential contributor to functional outcomes of the participants.

Length of stay Length of stay (LOS) was calculated as the number of nights spent in the acute hospital setting.

Despite previous studies indicating that LOS is influenced by many factors other than the physical function of the patient [29–34], LOS remains a commonly used outcome measure for evaluating the success of ERP and benchmarking performance amongst healthcare organisations and thus was recorded for completeness.

Procedure

All participants underwent primary, unilateral TKA or THA procedures and received usual pre- and post-operative care in The Wesley Hospital, consistent with the existing ERP, under the direction of their treating surgeon and independent of the research. Usual physiotherapy care involved day of surgery (DOS) mobilisation (as appropriate), bidaily physiotherapy on POD 1–3 (including weekends), and daily physiotherapy on subsequent days (at the discretion of the treating physiotherapist) until time of discharge or transfer to inpatient rehabilitation. Physiotherapy incorporated range of motion and strengthening exercises, transfer practice, gait re-education, progression of mobility aids and distances walked, stairs practice, and discharge planning.

Assessments of function were undertaken at predetermined time points (Table 1). Pre-operative function was assessed 1–4 weeks pre-operatively during a usual pre-admission appointment. Assessments of post-operative function were conducted during usual post-operative physiotherapy care, on the afternoon of POD 2, and on the morning of discharge from the orthopaedic ward. The TUG and 10mWT were assessed at each time point only if the participant was judged to be able to perform the test safely and independently (using their customary mobility aid). For both the TUG and the 10mWT, time was recorded with a stopwatch (in seconds), and participants were instructed to perform the tests as quickly as possible, without compromising their safety. At each time point, two TUG trials were completed, and the faster of the two times was recorded. For the 10mWT, only one trial was assessed at each time point. For the mILAS, participants were scored based on the same mobility aid they used when performing the TUG and 10mWT.

Table 1 Time points for assessment of pain and functional measures

Time point	Assessments of pain and function
Pre-admission clinic	EuroQol-5 Dimension Visual Analogue Scale
	Oxford Hip or Knee Score
	Visual analogue scale
	Modified Iowa Level of Assistance Scale
	Timed Up and Go
	10-metre walk test
Post-operative day 2	Visual analogue scale
	Modified Iowa Level of Assistance Scale
	Timed Up and Go
	10-metre walk test
Day of discharge	Visual analogue scale
	Modified Iowa Level of Assistance Scale
	Timed Up and Go
	10-metre walk test
Six months post-operative (50% of cohort only)	EuroQol-5 Dimension Visual Analogue Scale
	Oxford Hip or Knee Score

A data collection form was devised to record the potential prognostic factors and the results of outcome measures for each participant. Information was entered into a secure database, and subsequently, all participants were de-identified prior to data analysis. Patient factors were recorded during a pre-operative subjective assessment; surgical and post-operative factors were extracted from the patient medical chart. Discharge date was recorded and defined as the date each participant was discharged from the acute orthopaedic ward to a suitable home environment or to inpatient rehabilitation. Patient readiness to discharge home was mutually determined by the patient and treating surgeon, with guidance from the treating physiotherapist based on ERP discharge criteria (Appendix 3) and independent of the research. Admission to inpatient rehabilitation was based on consideration of patients' post-operative medical or functional status and availability of appropriate social support, and independent of the research.

Data collection and assessment of all outcome measures were conducted by qualified physiotherapy staff. If participants were unable to perform any of the functional assessments at a particular time point (Table 1), the reason for this was recorded. Longer-term functional outcomes were assessed via telephone interview at 6 months post-operatively, for participants who comprised the first half of the study cohort.

Statistical analysis

A recruitment target of 350 participants was planned for the study, based on power calculations conducted using G*Power software (version 3.1.9.2, 2014). This number of participants allowed sufficient numbers to ensure statistical power of at least 80% to detect small to moderate levels of association between the prognostic factors of interest and the primary outcome measure, if such existed in the underlying population, using multiple linear regression analyses and a significance level of 0.05.

All statistical analyses were conducted using SPSS (IBM, version 26, 2019). Descriptive analyses were first conducted to describe the study cohort and variables of interest and to identify missing values. Distributions of all continuous prognostic factors and outcome measures were assessed, with normality and outliers assessed via visual inspection of histograms, box plots, and normal QQ plots, to inform decisions regarding the removal of outliers and approaches to statistical analysis. Independent samples t tests, Mann-Whitney U tests, and chi-square tests were used, as appropriate based on variable types and distributions, to assess baseline differences between the two surgical groups (TKA and THA) in demographics, other prognostic factors, and outcome measures.

To enable assessment of the linearity or other form of relationships between continuous prognostic and outcome variables and so inform decision-making about whether linear regression analyses would be appropriate to use to assess prognostic relationships, simple error bar charts were developed and visually inspected. For this purpose, continuous prognostic factors were first categorised into equal intervals, and then, where needed to ensure at least 10 participants in each category, two or more categories at either or both ends of the range of values for each variable were collapsed to form single categories.

Where linearity of relationships was evident, correlations between each of the ordinal or continuous prognostic factors and POD 2 mILAS were determined using Pearson's and Spearman's correlation analyses, as appropriate. Relationships between each of the nominal (dichotomous) prognostic factors and POD 2 mILAS were assessed using point biserial correlation analyses. Only prognostic factors that were significantly associated with POD 2 mILAS at the 0.1 level of statistical significance were included in subsequent multiple linear regression analyses. Nominal prognostic factors with sub-groups of less than 30 participants were also excluded from subsequent analyses due to the impacts of small sub-groups on statistical power to detect associations.

Prior to the conduct of multiple linear regression modelling, Pearson's correlation analyses were undertaken to identify collinearity among continuous prognostic factors. Similarly, point biserial correlation analyses were undertaken to determine whether any dichotomous prognostic factors were substantially correlated with the continuous prognostic factors. Pairs of factors for which the correlation analyses yielded $r > 0.7$ were identified, and in any such instances, one of the two correlated factors was removed from the subsequent regression analyses, based on pragmatic considerations which were recorded. Backward, stepwise, multiple linear regression analysis was then used to determine the combination of prognostic factors that best predicted POD 2 mILAS, with the level of statistical significance set at 0.05 for retention of any prognostic factor in the final regression model. Regression models were determined in this way for the whole cohort and separately for each of the THA and TKA cohorts.

Results

The patient and participant flow through the study is depicted in Fig. 1.

Descriptive statistics for patient characteristics assessed pre-operatively are presented in Table 2. Statistically significant differences existed between THA and TKA groups for mean body mass index (BMI) ($p = 0.002$), ASA grade distribution ($p < 0.001$), patient-reported pre-operative function as determined by mean OHS or OKS scores ($p = 0.02$), and mean Risk And Prediction Tool (RAPT) score ($p = 0.03$). However, with the exception of ASA grade distributions, these differences were not of a sufficient magnitude to be considered clinically important.

Descriptive statistics for surgical prognostic factors extracted from medical records are presented in Table 3. A statistically significant difference was identified between THA and TKA groups only for anaesthetic method–general anaesthetic (GA) only ($p = 0.04$).

Primary outcome measure

POD 2 mILAS

For the overall cohort, POD 2 mILAS scores ranged from 0 to 27, with a mean score (± SD) of 11.34 (± 6.2) points, and there were no missing values. The mean score for the THA group was 9.85 (± 6.0) and for the TKA group 12.06 (± 6.1), giving a statistically significant mean difference between the 2 groups of 2.21 points (95% CI, 0.85, 3.57), $t(352) = 3.187$, $p = 0.02$. Linearity was established for the relationships between POD 2 mILAS and all continuous and ordinal prognostic factors. However, following visual inspection of boxplots, three significant outliers were identified, and these participants were removed from further analysis with reasons recorded (Fig. 1). The levels of association between the individual prognostic factors and POD2 mILAS scores are presented in Table 4.

BMI, pre-operative pain (VAS), tourniquet duration, tourniquet pressure, oral analgesia only, TKA surgical approach, single-shot regional block, and regional block infusion were excluded from the subsequent regression analyses as no statistically significant association was identified between these prognostic factors and POD 2 mILAS scores at the 0.1 level of significance. ASA grade was not included in the regression model due to too few case numbers in ASA grades 1 and 4. Instead, Spearman's correlation analysis was used to gauge the strength of the relationship between ASA grade and POD 2 mILAS scores, and a weak but statistically significant positive correlation ($r_S = 0.17$ (329), $p = 0.002$) was

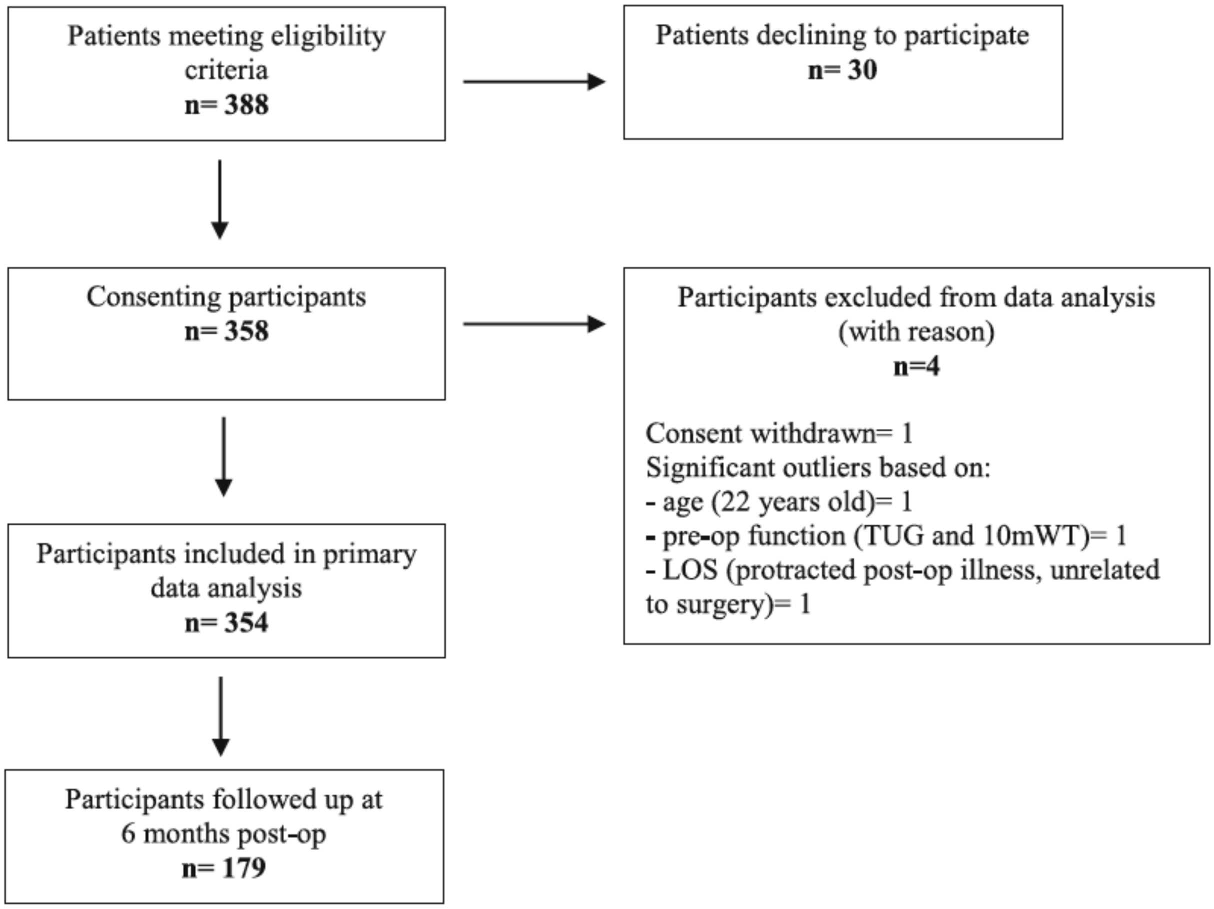

Fig. 1 Study flow diagram

identified. Robot-assisted surgery was removed from TKA and THA analyses due to too few participants having undergone this type of surgery, once the cohort was split by surgical type. Pre-operative TUG time and pre-operative 10mWT time were highly correlated, r = 0.880, and so, the prognostic factor pre-operative 10mWT was not included in the subsequent regression analyses. This decision to remove the 10mWT rather than TUG from the subsequent regression analyses was made due to variation within the literature regarding the methodology of the 10mWT [35], and thus, its implementation in clinical practice was considered to be potentially less standardised than implementation of the TUG.

The final regression model for prediction of POD 2 mILAS scores in the overall combined TKA and THA cohort, based on significant prognostic factors, is depicted in Table 5, with R^2 of 34.7% and adjusted R^2 of 33.1%, reflecting a medium effect size [36], and with $F(8, 329) = 21.882$, $p < 0.001$. POD 2 mILAS scores (i.e. level of functional dependence of the patient) increased an average of 0.20 points for every year of age, after the other significant prognostic factors were considered (Table 5). POD 2 mILAS scores were on average 1.67 points higher for females than males and decreased an average of 0.05 points for every additional point reported on the EQ-5D VAS general health scale (Table 5). Pre-operative TUG time was a further significant prognostic factor, with POD 2 mILAS scores increasing on average 0.45 points for every additional second a patient required to complete the TUG (Table 5). Among the surgical factors, arthroplasty site was a significant prognostic factor, with POD 2 mILAS scores on average 2.21 points higher in patients who underwent a TKA rather than a THA procedure (Table 5). POD 2 mILAS scores were on average 2.07 points lower in patients who received general anaesthesia (GA) only, when compared to those who received other forms of anaesthesia (Table 5). Similarly, POD 2 mILAS scores were on average 3.02 points lower in patients who received local infiltration analgesia (LIA), when compared to those patients who did not, and POD 2 mILAS scores were on average 2.02 points higher in

Table 2 Descriptive statistics. Patient characteristics, assessed pre-operatively

Patient characteristic	Total cohort, $N = 354$	TKA, $n = 238$ (67.2%)	THA, $n = 116$ (32.8%)	p value
Age (years), mean (SD)	68.9 (9.2)	69.5 (8.9)	67.7 (9.9)	0.09
Sex, *N* (%)				0.30
Female	185(52.0%)	129 (54.2%)	56 (48.3%)	
Male	169 (48.0%)	109 (45.8%)	60 (51.7%)	
BMI (kg/m^2)				
Median (IQR)	30.0 (26.6, 33.6)	30.3 (27.0, 34.5)	28.4 (26.1, 31.3)	0.002*
Range	(18.1–48.8) Missing: $n = 1$ (0.3%)	(18.1–48.8)	(18.9–45.8)	
ASA grade, *N* (%)				
1	27 (8.2%)	12 (5.5%)	15 (13.5%)	< 0.001*
2	180 (54.4%)	111 (50.5%)	69 (62.2%)	
3	122 (36.9%)	97 (44.1%)	25 (22.5%)	
4	2 (0.6%)	0 (0%)	2 (1.8%)	
Median (IQR)	2 (2, 3) Missing: $n = 23$ (6.5%)	2 (2, 3)	2 (2, 2)	
Pre-operative Hb (g/L)				
Mean (SD)	137.9 (11.8) Missing: $n = 4$ (1.1%)	137.5 (11.6)	138.7 (12.1)	0.40
Pre-operative pain (VAS 0–100)				0.05
Mean (SD)	38.9 (26.3) Missing: $n = 6$ (1.7%)	37.0 (26.7)	42.8 (25.0)	
Pre-operative function				
OKS/OHS (0–48)				
Mean (SD)	25.5 (8.0) Missing: $n = 2$ (0.6%)	26.0 (8.0)	23.7 (7.9)	0.02*
EQ-5D VAS (0–100)				
Median (IQR)	80 (70, 90)	80 (70, 90)	80 (65, 90)	0.11
Range	(10–100) Missing: $n = 4$ (1.1%)	(10–100)	(18–100)	
mILAS (0-36)				
Median (IQR)	0 (0.0, 0.0)	0 (0.0, 0.0)	0 (0.0, 0.0)	0.16
Range	(0–11)	(0–11)	(0–11)	
TUG (s)				
Median (IQR)	8.79 (7.41, 11.09)	8.76 (7.58, 11.05)	8.98 (7.17, 11.28)	0.56
Range	(4.39–30.93)	(4.97–29.29)	(4.39–30.93)	
10mWT (s)				
Median (IQR)	7.61 (6.49, 9.40)	7.65 (6.52, 9.40)	7.58 (6.44, 9.42)	0.71
Range	(4.23–27.02)	(4.23–22.94)	(4.75–27.02)	
RAPT score				
Mean (SD)	9.48 (2.1) Missing: $n = 5$ (1.4%)	9.3 (2.2)	9.8 (2.0)	0.03*

Missing data: was omitted during pre-admission assessment or could not be extracted from patient medical chart

ASA American Society of Anaesthesiologists, *BMI* body mass index, *EQ-5D VAS* EuroQol-5 Dimension Visual Analogue Scale, *Hb* haemaglobin, *IQR* inter-quartile range, *mILAS* modified Iowa Level of Assistance Scale, *OKS* Oxford Knee Score, *OHS* Oxford Hip Score, *RAPT* Risk Assessment and Prediction Tool, *THA* total hip arthroplasty, *TKA* total knee arthroplasty, *TUG* Timed Up and Go test, *VAS* visual analogue scale, *10mWT* ten-metre walk test

*Statistical significance assessed at the 0.05 level. *p* values were derived from an independent-samples *t*-test, Mann-Whitney *U* test, or chi-square test comparing TKA and THA cohorts, as appropriate for variable type

Table 3 Descriptive statistics. Surgical prognostic factors

Surgical factor	Total cohort, *N* = 354	TKA, *n* = 238 (67.2%)	THA, *n* = 116 (32.8%)	*p* value
Tourniquet duration				N/A
(mean [SD] min)		59.0 (21.5) *n* = 231 (missing *n* = 7)		
Tourniquet pressure				N/A
(mean [SD] mmHg)		292.5 (29.1) *n* = 231 (missing *n* = 3)		
Surgical approach, *N* (%)				N/A
Parapatellar TKA		228 (95.8%)		
Subvastus TKA		10 (4.2%)		
Posterior approach THA			71 (61.2%)	
Direct anterior approach THA			22 (19.0%)	
Direct superior approach THA			23 (19.8%)	
Robot-assisted surgery, *N* (%)				0.16
No	318 (89.8%)	210 (88.2%)	108 (93.1%)	
Yes	36 (10.2%)	28 (11.8%)	8 (6.9%)	
Duration of surgery (min)				0.67
Median (IQR)	79 (70, 93)	79 (71, 91)	79 (67, 100)	
Range	(37–178)	(37–178)	(49–167)	
Anaesthetic method, *N* (%)				
GA only	97 (27.4%)	57 (23.9%)	40 (34.5%)	0.04*
GA + spinal LA	198 (55.9%)	145 (60.9%)	53 (45.7%)	0.07
Sedation + spinal LA	55 (15.5%)	34 (14.3%)	21 (18.1%)	0.35
Other (intrathecal morphine)	4 (1.1%)	2 (0.8%)	2 (1.7%)	N/A
Initial analgesia, *N* (%)				
Intra-operative LIA	294 (83.1%)	214 (89.9%)	80 (69.0%)	< 0.001*
PCA	76 (21.5%)	49 (20.6%)	27 (23.3%)	0.56
Oral analgesia only	27 (7.6%)	7 (2.9%)	20 (17.2%)	< 0.001*
Intra-articular catheter		113 (47.5%)	N/A	
Single-shot regional block		31 (13.0%)	N/A	
Ambulatory regional block		25 (10.5%)	N/A	

Missing data: could not be extracted from patient medical chart
GA general anaesthesia, *IQR* inter-quartile range, *LA* local anaesthesia, *LIA* local infiltration analgesia, *PCA* patient-controlled analgesia, *THA* total hip arthroplasty, *TKA* total knee arthroplasty
*Statistical significance assessed at the 0.05 level. *p* values were derived from an independent-samples *t* test, Mann-Whitney *U* test, or chi-square test comparing TKA and THA cohorts, as appropriate for variable type

patients who received post-operative analgesia via patient-controlled analgesia (PCA) when compared to those patients who did not (Table 5).

The final regression model for prediction of POD 2 mILAS scores in the TKA group, based on significant prognostic factors, is depicted in Table 6, with R^2 of 36.4% and adjusted R^2 of 34.1%, reflecting a medium effect size [36], and with $F(8, 220) = 15.723$, $p < 0.001$. POD 2 mILAS scores increased on average 0.18 points for every year of age and were on average 1.49 points higher for females than males (Table 6). POD 2 mILAS scores decreased on average 0.09 points for every additional point reported on the EQ-5D VAS general health scale, and similarly increased an average of 0.50 points for every additional second a patient required to complete the TUG (Table 6). POD 2 mILAS scores were on average 2.07 points lower in patients who received a GA only, when compared to those who received other forms of anaesthesia (Table 6). POD 2 mILAS scores were on average 3.62 points lower in patients who received LIA, when compared to those patients who did not, and POD 2 mILAS scores were on average 2.35 points higher in patients who received post-operative analgesia via PCA when compared to those patients who did not (Table 6). POD 2 mILAS scores were also on average 0.03 points lower for every additional minute of surgical time (Table 6).

Table 4 Correlation between individual potential prognostic factors and POD 2 mILAS scores

Potential prognostic factors	*r* or r_S	*p* value
Patient-related factors		
Age	0.34	< 0.001*
Pre-operative Hb	− 0.19	< 0.001*
RAPT score	− 0.39	< 0.001*
Pre-operative patient-reported function (OKS/OHS)	− 0.16	< 0.001*
Pre-operative function (mILAS)	0.20	< 0.001*
Pre-operative function (TUG)	0.33	< 0.001*
Pre-operative function (10mWT)	0.34	< 0.001*
Gender (0 = female, 1 = male)	− 0.19	< 0.001*
ASA	0.17	0.002*
Pre-operative patient-reported general health (EQ-5D VAS)	− 0.11	0.04*
Pre-operative pain (VAS)	0.09	0.11
BMI	0.05	0.34
Surgical factors		
Surgical approach (THA cohort only) (0 = PA, 1 = DAA or DSA)	− 0.37	< 0.001*
LIA use	− 0.21	< 0.001*
Surgery duration	− 0.24	< 0.001*
PCA use	0.18	0.001*
Arthroplasty site (0 = THA, 1 = TKA)	0.17	0.002*
Intra-articular catheter (TKA cohort only)	− 0.19	0.003*
GA only	− 0.13	0.02*
Sedation and spinal anaesthesia	0.09	0.09*
Robot-assisted surgery	− 0.09	0.09*
Single-shot regional block (TKA cohort only)	0.08	0.21
Oral analgesia only	0.06	0.25
GA and spinal anaesthesia	0.03	0.53
Surgical approach (TKA cohort only) (1 = parapatellar approach, 2 = subvastus approach)	− 0.04	0.54
Ambulatory regional block (TKA cohort only)	0.04	0.57
Tourniquet pressure (TKA cohort only)	− 0.02	0.76
Tourniquet duration (TKA cohort only)	− 0.02	0.80

ASA American Society of Anaesthesiologists, *BMI* body mass index, *DAA* direct anterior approach, *DOS* day of surgery, *DSA* direct superior approach, *EQ-5D VAS* EuroQol-5 Dimension Visual Analogue Scale, *Hb* haemaglobin, *GA* general anaesthesia, *LIA* local infiltration analgesia, *mILAS* modified Iowa Level of Assistance Scale, *OKS* Oxford Knee Score, *OHS* Oxford Hip Score, *PA* posterior approach, *PCA* patient-controlled analgesia, *POD* post-operative day, *RAPT* Risk Assessment and Prediction Tool, *THA* total hip arthroplasty, *TKA* total knee arthroplasty, *TUG* Timed Up and Go test, *VAS* visual analogue scale, *10mWT* ten-metre walk test

*Statistical significance assessed at the 0.1 level. *p* values were derived from Pearson's correlation, Spearman's correlation, or point biserial correlation, as appropriate for variable type

The final regression model for prediction of POD 2 mILAS scores in the THA group, based on significant prognostic factors, is depicted in Table 7, with R^2 of 32.4% and adjusted R^2 of 30.4%, reflecting a medium effect size [36], and with $F(3, 105) = 16.742$, $p < 0.001$. POD 2 mILAS scores decreased an average of 0.94 points for every additional point scored on the RAPT, after the other significant prognostic factors were considered (Table 7). POD 2 mILAS scores increased on average 0.36 points for every additional second a patient required to complete the TUG (Table 7). THA surgical approach was a further significant prognostic factor, with POD 2 mILAS scores on average 4.67 points higher in patients who underwent THA via a posterior surgical approach when compared to other surgical approaches (direct anterior approach or direct superior approach; Table 7).

Independent samples *t* tests and chi-square tests revealed no statistically significant differences in age, ASA grade distributions, or measures of pre-operative function, between the THA surgical approach groups—posterior approach (PA) versus direct anterior approach (DAA) or direct superior approach (DSA).

Additional analyses revealed participants who mobilised on the DOS had lower mean POD 2 mILAS scores (10.43 ± 5.8) than those who first mobilised on POD 1 (13.64 ± 6.5), with a statistically significant difference of 3.21 points (95% CI, 1.81, 4.61), $t(352) = 4.513$, $p < 0.001$. In the overall cohort, 49.2% experienced barriers to post-operative progress (Table 8). Participants who experienced post-operative progress barriers had higher mean POD 2 mILAS scores (14.65 ± 5.5) than those who did not (8.13 ± 5.0), with a statistically significant difference of 6.52 points (95% CI, − 7.62, − 5.42), $t(352) = -11.636$, $p < 0.001$.

Secondary outcome measures

POD 2 TUG and POD2 10mWT

In the overall cohort, 75.7% and 76.3% of participants completed the POD 2 TUG and 10mWT, respectively. The reasons for non-completion of these outcome measures are as follows: 18.1% of the cohort failed to meet an appropriate level of functional independence, 2.5% were inadvertently omitted by the treating therapist, and approximately 3.0% were limited by symptoms including pain, nausea, dizziness, wound ooze, and diarrohea or were awaiting investigations. Due to the proportion of participants for whom this outcome data was missing, regression analyses were not completed for these outcome measures. However, Spearman's correlation revealed a moderate correlation between POD 2 mILAS scores and scores on each of the secondary outcome measures assessed on POD 2: POD 2 TUG $r(266) = 0.48$, $p < 0.001$, and POD 2 10mWT $r(268) = 0.39$, $p < 0.001$.

Longer-term (6 months) PROMs

As planned, 6 months follow-up and collection of data pertaining to longer-term outcomes were completed for

Table 5 Final prognostic model for post-operative day 2 functional recovery (POD 2 mILAS) in overall cohort

Prognostic factors	Unstandardized regression coefficient (*B*)	Standard error of the coefficient (SE_B)	95% CI for *B*	Standardized coefficient (ß)	*p* value
Constant/intercept	− 0.906	2.550	− 5.923, 4.111		0.723
Age	0.201	0.032	0.138, 0.264	0.297	< 0.001
Gender (0 = female, 1 = male)	− 1.671	0.571	− 2.795, − 0.547	− 0.134	0.004
Pre-operative patient-reported general health (EQ-5D VAS/100)	− 0.051	0.020	− 0.090, − 0.013	− 0.126	0.009
Pre-operative function (TUG, sec)	0.453	0.094	0.269, 0.637	0.241	< 0.001
Arthroplasty site (0 = THA, 1 = TKA)	2.223	0.631	0.982, 3.464	0.167	< 0.001
Anaesthetic—use of GA only	− 2.067	0.674	− 3.392, − 0.742	− 0.148	0.002
Initial analgesia—LIA use	− 3.022	0.848	− 4.690, − 1.355	− 0.184	< 0.001
Initial analgesia—PCA use	2.021	0.765	0.516, 3.526	0.134	0.009

Statistical significance assessed at the 0.05 level
CI confidence interval, *EQ-5D VAS* EuroQol-5 Dimension Visual Analogue Scale, *GA* general anaesthesia, *LIA* local infiltration analgesia, *PCA* patient-controlled analgesia, *TUG* Timed Up and Go test, *VAS* visual analogue scale

179 (50.6%) of the 354 participants included in the primary analyses. For this sub-group, the changes between baseline measures and measures assessed at 6 months post-operatively are presented in Table 9. The median increases in OHS and OKS scores for the THA and TKA sub-groups, respectively, exceeded the group MICs for these measures of 11 (OHS) and 9 points (OKS) [25] (Table 9). The OHS MIC, for individuals, of 8 points [25] was exceeded by 93.3% of the THA sub-group. Similarly, 82.9% of the TKA sub-group exceeded the OKS MIC for individuals of 7 points [25] (Table 9). An increase of only 1 point in the median change score for the EQ-5D VAS (Table 9) indicated that self-reported general health status did not differ significantly between pre-operative assessment and 6 months post-operative assessment for the participants followed up at 6 months post-operatively.

A small, negative statistically significant correlation existed between POD 2 mILAS score and OKS or OHS scores at 6 months post-operatively for the overall sub-group ($r(177) = -0.27$, $p < 0.001$), and similarly for the TKA sub-group ($r(116) = -0.19$, $p = 0.037$). A similar small, negative correlation of borderline statistical significance was found for the THA sub-group ($r(59) = -0.25$, $p = 0.052$). The correlation between POD 2 mILAS scores and EQ-5D VAS scores at 6 months post-operatively did not meet statistical significance for any of the studied cohorts.

For the THA sub-group, a moderate, positive, statistically significant correlation existed between OHS and EQ-5D VAS assessed at 6 months post-operatively ($r(59) = 0.39$, $p = 0.002$), and a non-statistically significant small, positive correlation was found between OKS and EQ-5D VAS assessed at the same time point for the

Table 6 Final prognostic model for post-operative day 2 functional recovery (POD 2 mILAS) for the TKA group

Prognostic factors	Unstandardized regression coefficient (*B*)	Standard error of the coefficient (SE_B)	95% CI for *B*	Standardized coefficient (ß)	*p* value
Constant/intercept	7.837	4.187	− 0.415, 16.090		0.063
Age	0.184	0.042	0.101, 0.267	0.263	< 0.001
Gender (0 = female, 1 = male)	− 1.487	0.696	− 2.859, − 0.116	− 0.120	0.034
Pre-operative patient-reported general health (EQ-5D VAS/100)	− 0.087	0.024	− 0.134, − 0.039	− 0.207	< 0.001
Pre-operative function (TUG, sec)	0.503	0.114	0.279, 0.728	0.263	< 0.001
Surgery duration (min)	− 0.033	0.016	− 0.064, − 0.002	− 0.125	0.038
Anaesthetic method: use of GA only	− 2.066	0.858	− 3.756, − 0.375	− 0.143	0.017
Initial analgesia: LIA use	− 3.619	1.193	− 5.971, − 1.267	− 0.179	0.003
Initial analgesia: PCA use	2.345	0.959	0.455, 4.235	0.154	0.015

Statistical significance assessed at the 0.05 level
CI confidence interval, *EQ-5D VAS* EuroQol-5 Dimension Visual Analogue Scale, *GA* general anaesthesia, *LIA* local infiltration analgesia, *PCA* patient-controlled analgesia, *TUG* Timed Up and Go test, *VAS* visual analogue scale

Table 7 Final prognostic model for post-operative day 2 functional recovery (POD 2 mILAS) for the THA group

Prognostic actors	Unstandardized regression coefficient (*B*)	Standard error of the coefficient (SE_B)	95% CI for *B*	Standardized coefficient (*ß*)	*p* value
Constant/intercept	17.614	3.824	10.031, 25.196		< 0.001
RAPT score (/12)	− 0.943	0.278	− 1.493, − 0.392	− 0.314	0.001
Pre-operative function (TUG, sec)	0.357	0.160	0.039, 0.674	0.205	0.028
Surgical approach (0 = PA, 1 = DAA or DSA)	− 4.671	1.016	− 6.686, − 2.656	− 0.373	< 0.001

Statistical significance assessed at the 0.05 level
CI confidence interval, *DAA* direct anterior approach, *DSA* direct superior approach, *PA* posterior approach, *RAPT* Risk Assessment and Prediction Tool, *THA* total hip arthroplasty, *TUG* Timed Up and Go test

TKA sub-group ($r(116) = 0.16$, $p = 0.093$). 44.1% of the overall sub-group reported health conditions unrelated to the arthroplasty undertaken during the study impacted their EQ-5D VAS assessed at 6 months post-operatively.

LOS

LOS ranged from 2 to 16 days across all participants, with a median LOS of 4 days for the overall cohort, and for each of the THA and TKA groups. Statistically significant correlations were found between multiple factors and LOS (Table 10). Patient-related factors that were significantly positively correlated with LOS included age, ASA grade, and pre-operative TUG time, 10mWT time, and mILAS score. Those significantly negatively correlated with LOS were pre-operative RAPT score, EQ-5D VAS, and OKS/OHS scores (Table 10). Surgical and post-operative factors significantly positively correlated with LOS included incidence of post-operative progress barriers and POD 2 mILAS, TUG, and 10mWT scores (Table 10). THA (rather than TKA) surgery, DAA or DSA (rather than PA) THA, use of GA alone, combined use of GA and spinal anaesthesia, intra-operative LIA use, and DOS mobilisation were all associated with shorter LOS than their alternatives (Table 10).

Table 8 Symptoms reported in medical records as impacting post-operative progress in overall cohort

Progress barriers	*N* (%)
Pain	100 (28.2%)
Nausea	47 (13.3%)
Dizziness/low BP/pre-syncope	53 (15.0%)
Drowsiness/fatigue	22 (6.2%)
Delirium/impulsiveness	14 (4.0%)
Wound ooze	12 (3.4%)
Anxiety	12 (3.4%)
Constipation	12 (3.4%)
Quads inhibition	9 (2.5%)
Other (including systemically unwell or medical condition unrelated to surgery)	25 (7.1%)

Discussion

This study assessed the strengths of the prognostic relationships between patient-related and surgical variables and inpatient functional recovery (as assessed by POD 2 mILAS score) and yielded prognostic models for inpatient functional recovery following THA and TKA. In addition, patient-related, surgical, and post-operative factors associated with hospital LOS were identified, and the relationships between inpatient functional outcomes and longer-term (6-month) patient-reported functional outcomes were assessed. Overall, the findings indicate that a range of patient-related factors assessed pre-operatively as well as surgical and post-operative factors were associated with inpatient functional outcomes and with LOS following THA and TKA. In addition, longer-term functional outcomes for these patients reflected their inpatient functional outcomes. These findings address a gap in the existing evidence base, highlight the importance of assessing and optimising functional outcomes in the inpatient period, and may usefully inform the further development of ERP employed for THA and TKA.

The final prognostic models for both the overall cohort and TKA group explained approximately one third of the variance in inpatient functional recovery. Both models included as significant prognostic factors patient age, sex, pre-operative patient-reported general health, pre-operative function (TUG), and GA, LIA, and PCA use. In addition to these factors, arthroplasty site was a prognostic factor for the overall cohort, and surgery duration was prognostic for the TKA group. The final prognostic model for the THA group differed, possibly due in part to the smaller number of THA participants in the overall cohort, and included pre-operative function (TUG time), RAPT score, and surgical approach. Again, the prognostic model developed for the THA group explained approximately one third of the variance in inpatient functional recovery. Importantly, noted in each of the models was the contribution of both patient-related and surgical factors. This is the first study, to our knowledge, to identify independent, potentially modifiable surgical factors prognostic for early functional recovery following TKA or THA. The recent systematic

Table 9 Differences in pre-operative and longer-term (6 months post-operative) patient-reported outcome measures

Patient-reported outcome measure	Baseline score Median (IQR) Range, *n*	6 months post-op score Median (IQR) Range, *n*	Change score[a] Median (IQR) Range, *n*	Change score exceeded MIC At group level[b], *n* (%) For individuals[c], *n* (%)
OHS	22.0 (17.25, 29.0) 5–39, *n* = 60	46.0 (44.0, 48.0) 22–48, *n* = 61	22.5 (16.0, 28.75) 1–42, *n* = 60	60 (100%) 56 (93.3%)
OKS	25.0 (19.0, 32.0) 7–42, *n* = 117	43.0 (38.75, 46.0) 26-48, *n* = 118	16.0 (9.5, 23.0) − 4.0–41.0, *n* = 117	117 (100%) 97 (82.9%)
EQ-5D VAS	80.0 (70.0, 90.0) 25–100, *n* = 178	85.0 (75.0, 90.0) 10–100, *n* = 179	1.0 (− 5.0, 12.5) − 75–50, *n* = 178	N/A

EQ-5D VAS EuroQol-5 Dimension Visual Analogue Scale, *IQR* inter-quartile range, *MIC* minimal important change, *OHS* Oxford Hip Score, *OKS* Oxford Knee Score
[a]Change score is the difference between pre-operative baseline score and 6 months post-operative score
[b]For assessment at the group level, an MIC of 11 and 9 points was used for the OHS and OKS, respectively (Beard et al. [28])
[c]For assessment of individual patients, an MIC of 8 and 7 points was used for the OHS and OKS, respectively (Beard et al. [28])

review conducted by Hewlett-Smith et al. [9] did not find evidence that any individual surgical factors (other than site of arthroplasty) were prognostic for early functional recovery following THA or TKA.

In the prognostic models for both the overall cohort and TKA group, LIA use was associated with greater functional recovery and had the greatest prognostic value in both of these models, whereas PCA use had a negative impact on predicted POD2 mILAS scores. LIA is thought to provide effective early post-operative analgesia (without motor blockade), with less incidence of post-operative complications such as nausea, and a lower requirement for supplemental oral opioids; however, there is only low-level evidence for these effects in THA [37] and TKA [38]. In addition, optimal volume, composition, and site of administration of LIA have not been confirmed [5]. Limiting use of PCA pumps in the routine arthroplasty population is strongly recommended due to associated functional impedance [5]. Although attachments were routinely removed by POD 2 in the current study, PCA use was significantly correlated with post-operative nausea ($p < 0.001$) and dizziness ($p = 0.018$) in the overall cohort, which may explain its association with reduced functional recovery.

Less expected was the association between GA use and greater functional recovery in the overall cohort and TKA group. ERP literature has traditionally supported the use of spinal anaesthesia [4, 39, 40], although a meta-analysis of 29 studies including 10,488 patients reported no significant difference in the incidence of perioperative complications following THA and TKA when comparing neuraxial and general anaesthesia [41]. However, neuraxial methods were employed in significantly fewer patients than GA, and notably, epidural rather than spinal anaesthesia was the primary mode of neuraxial anaesthesia used [41]. Recently published anaesthesia consensus guidelines have reported low evidence for primary TKA and low to moderate evidence for primary THA in favour of neuraxial anaesthesia versus GA [42]. However, lack of detailed information regarding the potentially wide variability in GA technique, in addition to the significant evolution in GA, and the potential influence of modern GA technique on outcomes were also acknowledged [42].

Surprisingly, longer surgery duration was prognostic of greater recovery for the TKA group. It was, however, found to have the least prognostic value in this model. As surgery duration may be influenced by multiple factors including surgeon experience, anaesthetic technique, surgical approach, surgical technique, and complexity of surgical procedure, the clinical relevance of this particular finding is unclear.

In contrast, surgical approach was strongly prognostic of greater inpatient functional recovery in the THA group, making a difference of 4.7 points on the 36-point mILAS scale. This may be due to the muscle-sparing nature of the DAA and DSA compared to the PA THA, for which inpatient functional recovery was poorer. A systematic review [43] confirms that few studies have compared THA surgical approaches using inpatient function as an outcome. Achievement of early post-operative functional goals has been reported in favour of DAA compared to PA THA [16, 44, 45]. Recent guidelines, however, found inconclusive evidence regarding the effect of different surgical approaches on time to meet discharge criteria following THA in an enhanced recovery setting; adequately powered randomised controlled trials were recommended [5, 8]. Presently, this study valuably adds to the evidence available to inform practice in this area. Overall, with regard to surgical factors, our results indicate that DAA or DSA for THA, use of GA only, and LIA use were all associated with greater levels of post-operative functional recovery on POD 2, and thus warrant consideration as key ERP components.

With respect to site of arthroplasty, a statistically significant difference in POD2 mILAS scores was found in favour of the THA group; however, this may be, in part, due to the significant difference identified in ASA grade distributions between the TKA and THA groups. Although the THA group had lower pre-operative

Table 10 Association between individual potential prognostic factors and length of stay in overall cohort

Potential prognostic factors	r_S or *U*, *Z* values IQR LOS (nights) for groups	*p* value
Patient-related factors		
Gender (0 = female, 1 = male)	14685.0, − 1.022 IQR female (4.0–5.0), IQR male (4.0–5.0)	0.31
Age	0.20	< 0.001**
BMI	0.06	0.29
ASA	0.12	0.03*
Hb	− 0.03	0.54
Living situation	0.04	0.51
RAPT score	− 0.27	< 0.001**
Pre-op pain (VAS)	0.08	0.15
Pre-op patient-reported general health (EQ-5D VAS)	− 0.11	0.03*
Pre-op patient-reported function (OKS/OHS)	− 0.18	0.001**
Pre-op function (mILAS)	0.20	< 0.001**
Pre-op function (TUG)	0.26	< 0.001**
Pre-op function (10mWT)	0.21	< 0.001**
Surgical factors		
Arthroplasty site (0 = THA, 1 = TKA)	12065.0, − 1.996 IQR THA (3.0–5.0), IQR TKA (4.0–5.0)	0.05*
Robot-assisted surgery (0 = no, 1 = yes)	5337.0, − 0.690 IQR no (4.0–5.0), IQR yes (3.25–5.0)	0.49
GA only (0 = no, 1 = yes)	10172.5, − 2.769 IQR no (4.0–5.0), IQR yes (3.0–5.0)	0.006**
GA and spinal anaesthesia (0 = no, 1 = yes)	13215.0, − 2.419 IQR no (3.0–5.0), IQR yes (4.0–5.0)	0.02*
Sedation and spinal anaesthesia (0 = no, 1 = yes)	7972.0, − 0.373 IQR no (4.0–5.0), IQR yes (4.0–5.0)	0.71
LIA use (0 = no, 1 = yes)	7150.0, − 2.398 IQR no (4.0–5.75), IQR yes (4.0–5.0)	0.02*
PCA use (0 = no, 1 = yes)	9709.0, − 1.122 IQR no (4.0–5.0), IQR yes (4.0–6.0)	0.26
Intra-articular catheter (TKA only) (0 = no, 1 = yes)	6671.0, − 0.755 IQR no (4.0–5.0), IQR yes (4.0–5.0)	0.45
Single-shot regional block (TKA only) (0 = no, 1 = yes)	2566.5, − 1.867 IQR no (4.0–5.0), IQR yes (4.0–6.0)	0.06
Ambulatory regional block (TKA only) (0 = no, 1 = yes)	2437.0, − 0.720 IQR no (4.0–5.0), IQR yes (3.0–5.5)	0.47
Surgical approach (THA only) (0 = PA, 1 = DAA or DSA)	975.5, − 3.645 IQR PA (4.0–5.0), IQR DAA or DSA (3.0–4.0)	< 0.001**
Surgery duration	− 0.03	0.52
Tourniquet duration (TKA only)	− 0.02	0.94
Tourniquet pressure (TKA only)	− 0.02	0.50
Post-operative factors		
DOS mobilisation (0 = no, 1 = yes)	10,659.0–2.443 IQR no (4.0–6.0), IQR yes (4.0–5.0)	0.02*
Incidence of post-operative progress barriers (0 = no, 1 = yes)	8482.5, − 7.735 IQR no (3.0–4.0), IQR yes (4.0–6.0)	< 0.001**

Table 10 Association between individual potential prognostic factors and length of stay in overall cohort *(Continued)*

Potential prognostic factors	r_S or *U*, *Z* values IQR LOS (nights) for groups	*p* value
POD 2 mILAS	0.54	< 0.001**
POD 2 TUG	0.31	< 0.001**
POD 2 10mWT	0.28	< 0.001**

p values were derived from Spearman's correlation or Mann-Whitney *U* test, as appropriate for variable type
ASA American Society of Anaesthesiologists, *BMI* body mass index, *DAA* direct anterior approach, *DSA* direct superior approach, *DOS* day of surgery, *EQ-5D VAS* EuroQol-5 Dimension Visual Analogue Scale, *GA* general anaesthesia, *Hb* haemaglobin, *IQR* inter-quartile range, *LIA* local infiltration analgesia, *LOS* length of stay, *mILAS* modified Iowa Level of Assistance Scale, *OKS* Oxford Knee Score, *OHS* Oxford Hip Score, *PA* posterior approach, *PCA* patient-controlled analgesia, *POD* post-operative day, *RAPT* Risk Assessment and Prediction Tool, *THA* total hip arthroplasty, *TKA* total knee arthroplasty, *TUG* Timed Up and Go test, *VAS* visual analogue scale, *10mWT* ten-metre walk test
*Statistical significance $p < 0.05$ level
**Statistical significance $p < 0.01$ level

comorbidity overall (Table 1), both arthroplasty groups had a median ASA grade of 2. Additionally, the THA group had a greater proportion of patients receiving GA only (also a significant prognostic factor for POD 2 mILAS scores); however, site of arthroplasty and use of GA only were both significant independent prognostic factors within the final prognostic model for the overall cohort. Few studies have investigated site of arthroplasty as a prognostic factor for early post-operative functional outcomes. Although methodological quality limited the generalisability of the results, significantly slower functional recovery was observed in TKA patients when compared to THA patients at 1 week post-operatively [46, 47].

Interestingly, several potentially modifiable patient-related factors were significantly prognostic for POD 2 mILAS scores. These include pre-operative TUG time, RAPT score, and self-reported general health status (EQ-5D VAS). TUG time was the only prognostic factor to feature in each of the final models. Findings for the overall cohort indicate that every 5-s increase in time to complete the pre-operative TUG test equates to an increase of 2.25 points in the mean predicted POD 2 mILAS score, representing poorer functional recovery. This finding is relevant particularly for patients of lower pre-operative functional status and supports the available evidence for pre-operative conditioning. The prognostic value of pre-operative TUG time, specifically, has been supported by a strong level of evidence in TKA studies, but only limited evidence in studies of THA [9]. A further study, not included in the systematic review [9], also reported pre-operative TUG time in their final predictive model for functional recovery following THA [16].

Higher RAPT scores were strongly prognostic of greater POD 2 functional recovery in the THA model, such that a difference of 5 points on the RAPT would be associated with a mILAS difference of 4.7 points (equal to that associated with a change in THA surgical approach). Developed as a screening tool to predict discharge destination following THA and TKA, the RAPT score assigns values to the patient's age, sex, pre-operative exercise tolerance, the necessity for a mobility aid or community services, and social support upon discharge [48]. Although the RAPT score is primarily determined by non-modifiable factors, scoring of the exercise tolerance item and potentially the mobility aid item may be improved by optimising pre-operative function. The RAPT has only been identified in one other study as a potential predictor for early functional recovery [16] and was not included in their final prediction model.

Pre-operative patient-reported general health status had limited prognostic value in the models for both the overall cohort and TKA group. As expected, poorer pre-operative general health was associated with lower levels of post-operative functional recovery; however, a difference of 20 points on the EQ-5D VAS would be required to effect a change of 1.0 and 1.8 points in mILAS score for the overall cohort and TKA group, respectively. Furthermore, only a weak, statistically significant positive correlation was identified between ASA grade and POD 2 mILAS scores. This finding is in contrast with the strong and moderate levels of evidence for TKA and for THA, respectively, previously reported for an association between comorbidity status (ASA grade) and early post-operative functional outcomes [9].

Slower functional recovery was apparent for patients of older age and female sex in the overall cohort and TKA group. To date, two systematic reviews [9, 49] have reported conflicting evidence regarding an association between age and early post-operative functional recovery following THA [9, 49] and TKA [9]. Similarly, conflicting evidence was found for sex [9, 49] in studies of THA, whilst limited evidence supported an association between female sex and reduced early post-operative functional recovery in TKA studies [9].

Taken together, the identification of these patient-related prognostic factors supports pre-operative screening to identify patients of older age, female sex, poorer pre-operative health and functional status, and scoring lower on the RAPT as they may be less likely to achieve an accelerated recovery per many ERP. The use of these prognostic models during pre-operative screening may facilitate organisational efficiency by assisting in the prediction of patient flow. Telehealth may be a viable option for pre-operative screening in patients with reduced access to services [50] and avoids a significant cost burden to both patients and healthcare organisations [51]. Prehabilitation may significantly impact pre-operative TUG time, as well as exercise tolerance, thus potentially improving RAPT score and general well-being. As per the prognostic model, improvement in pre-operative function would result in changes to predicted early post-operative functional recovery.

Few studies, to our knowledge, have linked inpatient post-operative function to longer-term outcomes. Our results are similar to Bade et al. [18] who found acute functional performance to be predictive of functional performance at 6 months post-operatively following TKA, although pre-operative functional performance was found to be a stronger predictor. The small association between POD 2 mILAS scores and patient-reported functional outcomes assessed via OKS and OHS at 6 months post-operatively found for the overall cohort and the TKA sub-group warrants further research with larger cohorts. Inpatient function does not appear to be associated with longer-term general health. However, the EQ-5D VAS requires the respondent to rate their health "today", thus providing a very specific "snap-shot" of health status, which may be influenced by numerous factors. In addition, although a positive correlation existed between 6 months post-operative OHS and OKS scores and EQ-5D VAS assessed at the same time, 44.1% of the overall sub-group reported health conditions other than the arthroplasty undertaken during the study impacted their EQ-5D VAS. Moreover, general health ratings remained largely static pre-operatively to post-operatively despite large improvements in joint-specific functional assessments (OHS and OKS).

Inpatient functional performance was significantly correlated with LOS in the overall cohort, and similar results have been reported by Poitras et al. [15]. Higher POD 2 mILAS scores may be a useful clinical indicator of patients at risk of prolonged LOS, enabling prompt post-operative planning for patients who are recovering function more slowly than expected. Weak correlations between all patient-related factors and LOS were identified in this study. This is in contrast to previously reported strong level evidence for higher ASA grade, greater number of comorbidities, and presence of heart or lung disease as predictors of longer LOS following THA [49]. THA surgical approach was the only surgical factor in this study to be moderately correlated with LOS. PA THA was associated with longer LOS than DAA or DSA. A study of 5341 THA procedures also found patients who received DAA or DSA THA had statistically significantly shorter LOS and a higher rate of discharge directly home [52].

Strengths of this study include the spectrum of patient and surgical prognostic factors and the use of standardised, validated functional performance measures which are clinically relevant, easily integrated into routine post-operative assessment, and appropriate to the time point at which they were assessed. The mILAS [11] was selected as the primary outcome measure as it incorporates tasks reflective of the ADL necessary to safely discharge home [53]. Versions of the mILAS have been used in similar studies; however, its implementation is heterogeneous and has thus limited the comparison of results. The study cohort is believed to be reflective of the general arthroplasty population, with few exclusion criteria implemented. To control for the potential influence of patient expectation on LOS, only patients who attended pre-admission clinic and received pre-operative education were included in the study.

There are several limitations of this study. The prognostic models are based on data from a single centre which has implemented a partially standardised ERP. To increase generalisability, the models require internal and external validation preferably in a multi-centre study, similarly involving non-standardised ERP. POD 2 was chosen as the time point to assess functional recovery to enable comparisons with studies examining ERP outcomes where a LOS of 2 days has been reported. However, with THA and TKA being performed as ambulatory surgery in some organisations, further studies with earlier post-operative assessment time points are needed. While LIA use was identified as a significant prognostic factor, variations in site of administration, volume, and content of LIA administered were not accounted for in this study. Similarly, differences in dosage parameters, content, or duration of PCA use were not addressed; thus, further research is required to determine the impact of these variables. The impact of robotic-assisted surgery could not be fully assessed due to its application in only a small volume of the study cohort. Currently, in this facility, robot-assisted surgery is primarily used for uni-compartmental knee arthroplasty which, to maximise homogeneity, was not included in this cohort. Due to insufficient case numbers, the role of muscle-sparing approaches for TKA was also not able to be assessed; thus, these surgical factors warrant further research. Further research is also necessary to determine cut-off points for age, pre-operative TUG time, pre-operative EQ-5D VAS, and RAPT score to further guide pre-operative screening.

Due to time constraints, only the first half of the study cohort was assessed for longer-term functional outcomes. Due to the natural evolution of enhanced recovery techniques during the period of data collection, this sample may have varied slightly, with regard to surgical factors, from the remainder of the cohort. To reduce the potential for missing data, participants were not required to attend the hospital for assessment of longer-term functional outcomes. Therefore, inpatient function and longer-term functional outcomes could not be directly compared due to the variance in outcome measures assessed. However, inpatient function and longer-term functional outcomes could both be directly compared to pre-operative functional outcomes.

Validated tools for assessing short-term post-operative function following lower limb arthroplasty are lacking [11, 54]. In the absence of a gold standard for evaluating functional recovery in acute hospital inpatients, the mILAS [11] was used in this study. However, a 30-point version of the mILAS has recently been described and validated by Elings et al. [55] which may be of greater clinical relevance as it only assesses functional tasks. Implementation of a valid, standardised performance measure, such as this newer version of the mILAS, would assist in objective assessment of post-operative functional recovery, identification of patients at risk of prolonged LOS, and evaluation of ERP interventions [54], and also facilitate the benchmarking of patient-centred outcomes between organisations.

Conclusions

This study identified several patient-related and surgical factors prognostic for early post-operative functional recovery. Patient-related factors included in the final prognostic models for the overall cohort and TKA group were age, sex, pre-operative general health status, and pre-operative TUG time. Pre-operative TUG time and RAPT score were prognostic in the final model for the THA group. Surgical prognostic factors for the overall cohort and TKA group were use of GA only, LIA use and PCA use, with the addition of arthroplasty site in the model for the overall cohort, and surgery duration in the TKA group. Surgical approach was the only surgical prognostic factor in the model for the THA group. THA surgery was prognostic for greater functional recovery at POD 2 than TKA surgery. Several patient-related, surgical, and post-operative factors were associated with acute hospital LOS. A correlation was found between functional ability at POD 2 and OKS/OHS, assessed at 6 months post-operatively. Validation of these findings is required, and assessment time points earlier in the post-operative period could be implemented. Prognostic models may facilitate the prediction of inpatient flow thus optimising organisational efficiency. In addition, surgical prognostic factors warrant consideration as potentially key ERP elements, associated with early functional recovery. Standardised functional outcome measures are needed to evaluate patient-centred ERP outcomes and to facilitate the processes of benchmarking, auditing, and improving ERP.

Appendix 1: Two-stage process for exclusion of patients with cognitive impairment

1st stage: Pre-admission screening

Patients were screened by an occupational therapist (OT) during their pre-admission interview. Initial cognitive screening occurred via the OT's observation of the patient during the interview as well as the following screening question. "Do you have any difficulties with your thinking or memory?"

If a *Yes* response was elicited with the above cognitive screening question:

The patient was flagged by the OT, and the Mini-Mental State Examination (MMSE) [10] was implemented by the patient's treating physiotherapist on the acute orthopaedic ward during hospital admission. Patients scoring 23 or less, out of a maximum possible score of 30 (indicating cognitive impairment), were subsequently excluded from the research study, and on that basis, their data was not included in the data set or analysis.

If a *No* response was elicited with the above cognitive screening question:

The patient was considered eligible to consent to participate in the research study. However, the OT flagged any patients whom exhibited signs of cognitive impairment during the interview despite answering "No" to the screening question, and the MMSE was performed by the patient's treating physiotherapist on the acute orthopaedic ward during hospital admission. Patients scoring 23 or less were subsequently excluded from the research study, and on that basis, their data was not included in the data set or analysis.

2nd stage: Noted poor post-operative progression

Any research study participant identified by their treating physiotherapist as not following a usual post-operative recovery due to possible cognitive impairment undertook an MMSE on the acute orthopaedic ward. Patients scoring 23 or less were subsequently excluded from the research study, and on that basis, their data was not included in the data set or analysis.

Appendix 2

Table 11 Modified Iowa Level of Assistance Scale (Kimmel et al. [12])

Score	Amount of assistance	Items 1–4	Item 5	Item 6
0	Independent	No assistance or supervision is necessary to safely perform the activity (with or without an assistive device/aid)	> 40 m	No assistive device
1	Standby	Nearby supervision is required; no contact is necessary	26–40 m	1 stick or crutch
2	Minimal	One point of contact is necessary, including helping with the application of the assistive device, getting legs on/off leg rest, and stabilising the assistive device	10–25 m	2 sticks
3	Moderate	Two points of contact needed (1–2 people)	5–9 m	2 elbow crutches
4	Maximal	Significant support—3 or more points of contact (> 1 person)	3–4 m	2 axillary crutches
5	Failed	Attempted activity but failed with maximal assistance	2 m	Frame (standard or wheelie)
6	Not tested	Test was not attempted due to medical reasons or reasons of safety	< 2 m	Gutter/platform frame, standing lifter, hoist, or unsafe to use aid

Modified Iowa Level of Assistance Scale items: 1—supine to sitting on the edge of the bed, 2—sit to stand, 3—walking, 4—negotiation of one step, 5—walking distance, 6—assistive device used

Appendix 3

Table 12 The Wesley Hospital Enhanced Recovery Pathway (ERP) discharge criteria for THA and TKA

Allied health	Independent with transfers in/out of bed and chair
	Walking independently with aid
	Able to negotiate stairs (with supervision, if needed)
	Equipment and follow-up physiotherapy organised
Nursing	Showering
	Toileting (bowels opened)
	Pain adequately controlled
	Wound and dressings reviewed (as appropriate)
	Discharge Planning (e.g. services organised if applicable, support person contacted)
Patient	Accepting of discharge plan

Version 1.0 12/2015

Abbreviations

ADL: Activities of daily living; ASA: American Society of Anaesthesiologists; BMI: Body mass index; DAA: Direct anterior approach; DSA: Direct superior approach; DOS: Day of surgery; EQ-5D VAS: EuroQol 5 Dimension Visual Analogue Scale; ERP: Enhanced Recovery Pathway; GA: General anaesthesia; Hb: Haemaglobin; IQR: Inter-quartile range; LIA: Local infiltration analgesia; LOS: Length of stay; MDC: Minimal detectable change; MIC: Minimal important change; mILAS: Modified Iowa Level of Assistance Scale; MMSE: Mini-Mental State Examination; OHS: Oxford Hip Score; OKS: Oxford Knee Score; OT: Occupational therapist; PA: Posterior approach; PCA: Patient-controlled analgesia; POD: Post-operative day; PROM: Patient-reported outcome measure; THA: Total hip arthroplasty; TKA: Total knee arthroplasty; TUG: Timed Up and Go; VAS: Visual analogue scale; 10mWT: Ten-metre walk test

Acknowledgements

The authors wish to acknowledge Ross Ferguson, Lisa Haigh, all physiotherapy staff involved in data collection, the staff of the orthopaedic wards and pre-admission clinic, Dr. Kate Brunello, Dr. Rohan Brunello, and Dr. Bjorn Smith at The Wesley Hospital, Brisbane, Australia, and Evelyn Rathbone, Bond University, Gold Coast, Australia, for their encouragement, support, and contributions.

Authors' contributions

Conception/planning: NHS, RP, WH. Data collection: NHS. Statistical analysis: NHS, RP, WH, VS. Results: NHS, RP. Discussion/conclusion: NHS, RP. Review/editing: NHS, RP, WH, VS, JF. The authors read and approved the final manuscript.

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Funding

This research was supported by an Australian Government Research Training Program Scholarship.

Availability of data and materials

Access to the dataset generated and analysed during the current study, subject to necessary ethics approvals, can be obtained by contacting the corresponding author (NHS). This dataset is not publicly available due to the presence of information that could compromise research participant privacy/consent.

Ethics approval and consent to participate

Ethics approval was obtained for this study from the Uniting Care Human Research Ethics Committee (HREC no. 2016.09.187) and Bond University Human Research Ethics Committee (HREC no. 15685). All study participants provided written informed consent.

Consent for publication
Not applicable

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

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Received: 29 May 2020 Accepted: 31 July 2020
Published online: 27 August 2020

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Appendix VI: Participant Information Consent Form- Prospective Cohort Study

The Wesley HOSPITAL
Caring for you for life

Participant Information Sheet/Consent Form
Health/Social Science Research - *Adult providing own consent*
The Wesley Hospital

Title	Predictors for early functional recovery following primary unilateral total hip and knee arthroplasty
Short Title	Factors influencing recovery after total hip or knee replacement
Protocol Number	2016.09.187
Principal Investigator	Nicola Hewlett-Smith
Associate Investigator(s)	Professor Rod Pope Professor Wayne Hing Associate Professor James Furness
Location	The Wesley Hospital, Brisbane

Part 1 What does my participation involve?

Introduction

As you will shortly be undergoing hip or knee replacement surgery, you are invited to take part in a research project being undertaken at The Wesley Hospital. This project is titled “Factors influencing recovery after total hip or knee replacement”.

This project will examine The Wesley Hospital’s current approach to the care provided to people undergoing this type of surgery, and identify potential areas of improvement to our service. Your contact details were obtained when you were booked to attend The Wesley Hospital Pre-admission Clinic.

This Participant Information Sheet/Consent Form tells you about the research project. It explains the processes involved with taking part. Knowing what is involved will help you decide if you want to take part in the research.

Please read this information carefully. Ask questions about anything that you don't understand or want to know more about. Before deciding whether or not to take part, you might want to talk about it with a relative, friend or local health worker.
Participation in this research is voluntary. If you don't wish to take part, you don't have to.

If you decide you want to take part in the research project, you will be asked to sign the consent section. By signing this section, you are telling us that you:

- Understand what you have read
- Consent to take part in the research project
- Consent to be involved in the research described
- Consent to the use of your personal and health information as described.

You will be given a copy of this Participant Information and Consent Form to keep.

What is the purpose of this research?
The purpose of the research study is to examine which factors most influence patient recovery after total hip and knee replacement surgery. A greater understanding of factors which most influence post-surgical recovery will allow health care providers to better anticipate patient needs, tailor treatments, and improve patient education before and after surgery.

<u>Background</u>
In October 2014, The Wesley Hospital Allied Health Department launched an Enhanced Recovery Program for patients undergoing total hip and knee replacement surgery.

Enhanced Recovery is an approach to patient care which is based on evidence from current research. Enhanced Recovery Programs (ERP) have been implemented in several countries worldwide and successfully applied to various surgical procedures including hip and knee joint replacement. Enhanced Recovery programs aim to help patients better prepare for their surgery, optimise aspects of the surgical journey and assist patients to achieve a more rapid recovery.

Most research studies regarding Enhanced Recovery methods have been undertaken in the UK and Europe within the Public Health system. This study aims to extend the research to an Australian private hospital setting.

The study aims to enrol 350 participants over an 18 month period and will be conducted solely at The Wesley Hospital.
The results of this research study will be used by the researcher Nicola Hewlett-Smith, a Senior Orthopaedic Physiotherapist at The Wesley Hospital, to obtain a Higher Degree by Research through Bond University, as well as inform the ongoing service improvement efforts at The Wesley Hospital.

This research has been initiated by the researcher, Nicola Hewlett-Smith, in consultation with Ross Ferguson, ERP Coordinator and Lisa Haigh, Head of Profession (Physiotherapy) at The Wesley Hospital.

What does participation in this research involve?
All patients undergoing a hip or knee replacement who have been deemed eligible by their Surgeon to participate in the Wesley Enhanced Recovery Program will be assessed for suitability to participate in the study.

If you are eligible and consent to participate in the study, your involvement will commence at your Pre-admission Clinic appointment and will cease when you are discharged from the orthopaedic ward. Approximately 50% of participants will be followed up via telephone (on one occasion only), at six months after their surgery, and you may be one of those participants if you consent to participate.
All patients undergoing total hip and knee replacement are routinely required to complete a series of outcome measures (questionnaires and assessments of physical function) before and after their surgery, as part of normal hospital care. The researchers will gather a copy of the results of these outcome measures for use in the research.

Outcome Measures for which the researchers will gather results from your medical records at each relevant time point are as follows, and will be further explained to you by the clinical staff of the hospital at the time they are conducted:

Time Point	Outcome Measures Performed
Pre-Admission Clinic	- EuroQol-5Dimension - Oxford Hip or Knee Score - Modified Iowa Level of Assistance Scale - Timed Up and Go - Ten Metre Walk Test -
Post-operative Day 2	- Modified Iowa Level of Assistance Scale - Timed Up and Go - Ten Metre Walk Test -
Day of Discharge	- Modified Iowa Level of Assistance Scale - Timed Up and Go - Ten Metre Walk Test - Enhanced Recovery Pathway Satisfaction survey -
Six Months Post-operative (50% cohort only)	- EuroQol-5Dimension - Oxford Hip or Knee Score -

Six Months After Surgery
Approximately half of the study participants will be contacted by telephone to reassess their Oxford Hip or Knee Score and EuroQol-5Dimension questionnaires. During this telephone call, participants will have the opportunity to discuss any post-surgical concerns and receive appropriate advice or referral, as necessary, from the member of the research team conducting the follow-up call.

Participant Eligibility
If you decide to take part in the research project, you will first be given a brief questionnaire asking about:

- whether you have had joint replacement surgery on this particular joint before;
- whether you are having more than one joint replaced during this particular surgery; and
- whether English is your first spoken language

and including a Mini Mental State Examination (MMSE), which is a commonly used quick screening test for cognitive function.

This will determine if you are eligible to take part. Completing the questionnaire will take approximately 5 minutes. If the screening questionnaire shows that you meet the requirements, then you will be able to start the research project. If the screening questionnaire shows that you cannot be in the research project, the research coordinator will discuss this with you.

Do I have to take part in this research project?
Participation in any research project is voluntary. If you do not wish to take part, you do not have to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. If you do decide to take part, you will be given this Participant Information and Consent Form to sign and you will be given a copy to keep.

Your decision whether to take part or not to take part, or to take part and then withdraw, will not affect your usual care, your relationship with professional staff or your relationship with The Wesley Hospital.

By signing the consent form, you consent to the research team collecting and using personal information about you for the research study. The personal information that the research team will collect and use includes demographic and surgical details gathered from your health records held at The Wesley Hospital; and information from the questionnaires and functional assessments listed in the table above.

The research will be supervised by Professor Wayne Hing and Assistant Professor James Furness from Bond University, as well as Professor Rod Pope from Charles Sturt University, who are all Physiotherapists. This research project has been designed to make sure the researchers interpret the results in a fair and appropriate way and avoids researchers or participants jumping to conclusions. There are no costs associated with participating in this research project, nor will you be paid.

What are the possible benefits of taking part?
There will be no clear benefit to you from your participation in this research. The findings from this study will add to the evidence base for Enhanced Recovery methods, specifically in an Australian private hospital setting for patients undergoing total hip or knee replacement surgery. Evidence, such as that gained from this study, informs clinicians and organisations regarding best practice methods for patient care. Future patients may then benefit from improved health outcomes following total hip and knee joint surgery, reduced risk of surgical

complications and shorter length of stay in hospital.

What are the possible risks and disadvantages of taking part?
The risks associated with participation in this research study are minimal and are outlined below:

Safety
The likelihood and severity of risk to participants' safety in this study are negligible. All participants will undertake a normal course of surgery and usual physiotherapy care before and after surgery.
Usual physiotherapy care involves daily assessment of several functional tasks to monitor progress and determine when patients are ready for discharge from hospital.
All usual precautions will be taken with respect to safety when performing assessments of functional ability.

Inconvenience
There will be a small time-burden of approximately 5 minutes associated with the completion of the screening questionnaire to determine eligibility to participate in the research study.

Approximately half the study participants will be contacted via telephone at six months after surgery for completion of long term outcome measures. This is expected to take 5-6 minutes and these participants will be provided with an opportunity to discuss any post-surgical issues and receive appropriate advice or referral, as necessary, from the research team member conducting the follow-up call.

Privacy
In any research where personal and health information is to be collected, there is a risk to the privacy of participants. The research team takes this risk seriously and will be managing your information very carefully and securely to manage this risk. Further details on how your information will be managed to address this risk are provided in a separate section below.

What if I withdraw from this research project?
If you do consent to participate, you may withdraw at any time. If you decide to withdraw from the study, you will suffer no disadvantage as you will continue to undertake a normal course of surgery and usual physiotherapy care regardless of participation in the study. If you do withdraw, you will be asked to complete and sign a 'Withdrawal of Consent' form; this will be provided to you by the research team.

If you decide to leave the research project, the researchers will not collect additional personal information from you, although personal information already collected will be retained to ensure that the results of the research project can be measured properly, and to comply with law. You should be aware that data collected up to the time you withdraw will form part of the research project results. If you do not want your data to be included, you must tell the researchers when you withdraw from the research project.

What happens when the research project ends?
Upon completion of the study, results will be published in a health-related journal and participants may receive a copy via email, if they request this from the researchers.
All reports and publications will be subject to detailed review by research and local hospital supervisors before being released into the public arena.

Part 2 How is the research project being conducted?

What will happen to information about me?
By signing the consent form you agree to the research team accessing personal information from your health records that is relevant to the research study.

Only health professionals employed by The Wesley Hospital who understand the confidential nature of medical records will be members of the research team who extract data from records for the study. Any information obtained for the purpose of this research study that can identify you will be treated as confidential and securely stored.

All data will be de-identified as soon as possible. This de-identification process will occur prior to data analysis, to prevent any risk of personal details being released when analysing or publishing the data.

A copy of the non-identifiable data set may be provided to research supervisors at Bond University and Charles Sturt University for a limited period, for the purpose of assistance with data analysis. Once analysis and reporting are complete, copies held at Bond University or Charles Sturt University will be securely deleted.
Individual participants, staff members, medical practitioners and their specific involvement will not be identifiable. Your information will only be used for the purpose of this research study and it will only be disclosed with your permission, or as required by law.

It is anticipated that the results of this research project will be published and/or presented in a variety of forums. All information will be published or presented in such a way that you cannot be identified.

In accordance with Australian and/or Queensland government privacy and other relevant laws, you have the right to request access to the information about you that is collected and stored by the research team.

You also have the right to request that any information with which you disagree be corrected. Please inform the research team member named at the end of this document if you would like to access your information, but please note that we will not be able to identify and give you access to your data once the data set is made non-identifiable.

Who is organising and funding the research?
This research study is being conducted by Nicola Hewlett-Smith, a Senior Orthopaedic Physiotherapist at The Wesley Hospital and has been approved by The Wesley Hospital and Bond University. No member of the research team will receive personal financial benefit

from your involvement in this research project (other than their ordinary wages).

Who has reviewed the research project?
All research in Australia involving humans is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this research project have been approved by the HREC of The Wesley Hospital and Bond University. This project will be carried out according to the *National Statement on Ethical Conduct in Human Research (2007)*. This statement has been developed to protect the interests of people who agree to participate in human research studies.

Further information and who to contact
The person you may need to contact will depend on the nature of your query. If you want any further information concerning this project or if you have any problems which may be related to your involvement in the project, you can contact:

Research contact person

Name	Nicola Hewlett-Smith
Position	Senior Orthopaedic Physiotherapist
Telephone	07 3232 7000 ask for Pager 757
Email	nicola.hewlett-smith@uchealth.com.au

If you have any complaints about any aspect of the project, the way it is being conducted or any questions about being a research participant in general, then you may contact:

Reviewing HREC and HREC Coordinator

Reviewing HREC name	Uniting Care Health HREC
HREC Coordinator	Shannon Lytras
Telephone	07 3232 7500
Email	ethics@uchealth.com.au

Consent Form - *Adult providing own consent*

Title	Predictors for early functional recovery following primary unilateral total hip and knee arthroplasty
Short Title	Factors influencing recovery after total hip or knee replacement
Protocol Number	2016.09.187
Principal Investigator	Nicola Hewlett-Smith
Associate Investigator(s)	Professor Rod Pope Professor Wayne Hing Associate Professor James Furness
Location	The Wesley Hospital, Brisbane

Declaration by Participant

- I have read the Participant Information Sheet or someone has read it to me in a language that I understand.
- I understand the purposes, procedures and risks of the research described in the project.
- I have had an opportunity to ask questions and I am satisfied with the answers I have received.
- I freely agree to participate in this research project as described and understand that I am free to withdraw at any time during the project without affecting my future care.
- I understand that I will be given a signed copy of this document to keep.

Name of Participant	**Signature**	**Date**
(please print)		

Declaration by Researcher†

I have given a verbal explanation of the research project, its procedures and risks and I believe that the participant has understood that explanation.

Name of Researcher	**Signature**	**Date**
(please print)		

An appropriately qualified member of the research team must provide the explanation of, and information concerning, the research project.
Note: All parties signing the consent section must date their own signature.

Form for Withdrawal of Participation - *Adult providing own consent*

Title	Predictors for early functional recovery following primary unilateral total hip and knee arthroplasty
Short Title	Factors influencing recovery after total hip or knee replacement
Protocol Number	2016.09.187
Principal Investigator	Nicola Hewlett-Smith
Associate Investigator(s)	Professor Rod Pope Professor Wayne Hing Associate Professor James Furness
Location	The Wesley Hospital, Brisbane

Declaration by Participant

I wish to withdraw from participation in the above research project and understand that such withdrawal will not affect my routine care, or my relationships with the researchers or The Wesley Hospital.

Name of Participant	**Signature**	**Date**
(please print)		

In the event that the participant's decision to withdraw is communicated verbally, the Senior Researcher must provide a description of the circumstances below.

Declaration by Researcher

I have given a verbal explanation of the implications of withdrawal from the research project and I believe that the participant has understood that explanation.

Name of Researcher	**Signature**	**Date**
(please print)		

An appropriately qualified member of the research team must provide information concerning withdrawal from the research project. Note: All parties signing this section must date their own signature.

Appendix VII: Two Stage Process For Exclusion Of Patients With Cognitive Impairment

1st Stage: Pre-admission screening

Patients were screened by an Occupational Therapist (OT) during their Pre-admission interview. Initial cognitive screening occurred via the OT's observation of the patient during the interview as well as the following screening question. "Do you have any difficulties with your thinking or memory?"

If a ***Yes*** response was elicited with the above cognitive screening question:
The patient was flagged by the OT and the Mini Mental State Examination (MMSE) (85) was implemented by the patient's treating physiotherapist on the acute orthopaedic ward during hospital admission. Patients scoring 23 or less, out of a maximum possible score of 30 on the MMSE, (indicating cognitive impairment), were subsequently excluded from the research study and on that basis their data was not included in the data set or analysis.

If a ***No*** response was elicited with the above cognitive screening question:
The patient was considered eligible to consent to participate in the research study. However, the OT flagged any patients whom exhibited signs of cognitive impairment during the interview despite answering "No" to the screening question; and the MMSE was performed by the patient's treating physiotherapist on the acute orthopaedic ward during hospital admission. Patients scoring 23 or less, were subsequently excluded from the research study and on that basis their data was not included in the data set or analysis.

2nd Stage: Noted poor post-operative progression

Any research study participant identified by their treating physiotherapist as not following a usual post-operative recovery due to possible cognitive impairment undertook an MMSE on the acute orthopaedic ward. Patients scoring 23 or less, were subsequently excluded from the research study and on that basis their data was not included in the data set or analysis.

Appendix VIII: Modified Iowa Level Of Assistance Scale

Modified Iowa Level of Assistance Scale (Kimmel et al. 2016)

Score	Amount of assistance	Items 1-4	Item 5	Item 6
0	Independent	No assistance or supervision is necessary to safely perform the activity (with or without and assistive device/aid)	>40 m	No assistive device
1	Standby	Nearby supervision is required; no contact is necessary	26-40 m	1 stick or crutch
2	Minimal	One point of contact is necessary, including helping with the application of the assistive device, getting legs on/off leg rest, and stabilising the assistive device	10-25 m	2 sticks
3	Moderate	Two points of contact needed (1-2 people)	5-9 m	2 elbow crutches
4	Maximal	Significant support- 3 or more points of contact (>1 person)	3-4 m	2 axillary crutches
5	Failed	Attempted activity but failed with maximal assistance	2 m	Frame (standard or wheelie)
6	Not tested	Test was not attempted due to medical reasons or reasons of safety	<2 m	Gutter/platform frame, standing lifter, hoist, or unsafe to use aid

Modified Iowa Level of Assistance Scale items: 1- supine to sitting on the edge of the bed, **2-** sit to stand, **3-** walking, **4-** negotiation of one step, **5-** walking distance, **6-** assistive device used.
Adapted from Phys Ther. 1995;75(3):169–176, with permission of the American Physical Therapy Association.

Appendix IX: EQ-5D English (UK) Sample Version

EQ-5D-5L

Health Questionnaire

English version for the UK

Under each heading, please tick the ONE box that best describes your health TODAY.

MOBILITY

I have no problems in walking about ❑

I have slight problems in walking about ❑

I have moderate problems in walking about ❑

I have severe problems in walking about ❑

I am unable to walk about ❑

SELF-CARE

I have no problems washing or dressing myself ❑

I have slight problems washing or dressing myself ❑

I have moderate problems washing or dressing myself ❑

I have severe problems washing or dressing myself ❑

I am unable to wash or dress myself ❑

USUAL ACTIVITIES *(e.g. work, study, housework, family or leisure activities)*

I have no problems doing my usual activities ❑

I have slight problems doing my usual activities ❑

I have moderate problems doing my usual activities ❑

I have severe problems doing my usual activities ❑

I am unable to do my usual activities ❑

PAIN / DISCOMFORT

I have no pain or discomfort ❑

I have slight pain or discomfort ❑

I have moderate pain or discomfort ❑

I have severe pain or discomfort ❑

I have extreme pain or discomfort ❑

ANXIETY / DEPRESSION

I am not anxious or depressed ❑

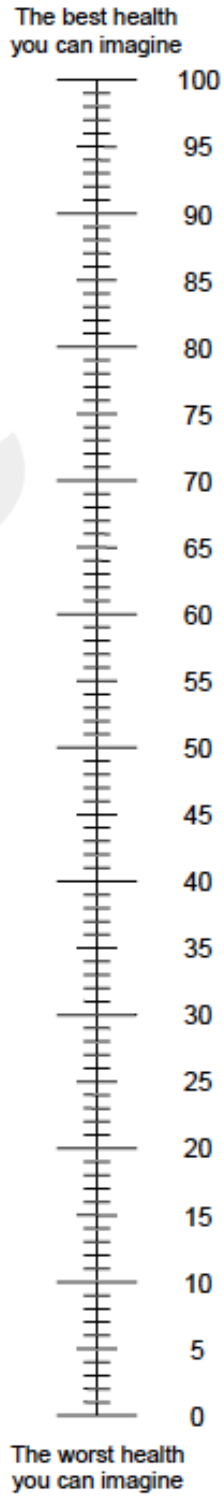
I am slightly anxious or depressed ❑

I am moderately anxious or depressed ❑

I am severely anxious or depressed ❑

I am extremely anxious or depressed ❑

- We would like to know how good or bad your health is TODAY.
- This scale is numbered from 0 to 100.
- 100 means the <u>best</u> health you can imagine.
  0 means the <u>worst</u> health you can imagine.
- Mark an X on the scale to indicate how your health is TODAY.
- Now, please write the number you marked on the scale in the box below.



YOUR HEALTH TODAY =

Appendix X: Data Collection Form

Patient Sticker

Date of Surgery: ____________

Patient Variables:

1. Age ____________

2. Gender ☐ Male ☐ Female

3. Height ____________ Weight ____________ BMI ____________

4. Patient Ethnicity ____________

5. Living situation
☐ lives with partner/family ☐ lives alone ☐ patient is in a primary carer role

6. Residence
☐ house/unit ☐ assisted living ☐ residential facility

7. Stairs ☐ yes ☐ no

8. Functional Co-morbidity Index score ____________

9. Pre-op Haemaglobin ____________

10. Pre-admission input
☐ ERP group class ☐ Individual consult ☐ Telephone interview ☐ Nil

11. Pre-op carbohydrate loading ☐ Yes ☐ No

12. Patient admitted on day of surgery (DOSA) ☐ Yes ☐ No

13. Planned discharge destination
☐ Home ☐ Stay with family/friend ☐ Inpatient rehab ☐ Other
If other, please state ____

14. Pre-op RAPT score ____________

Peri-operative Variables:

1. Surgery
☐ TKA ☐ TKA- parapatellar approach ☐ TKA- subvastus approach
☐ TKA- MAKO robot

☐ THA ☐ THA posterior approach ☐ THA anterior approach
☐ THA- MAKO robot ☐ THA direct superior approach

2. ASA Grade ____________

3. Type of anaesthesia
☐ GA ☐ GA + Spinal ☐Sedation + Spinal ☐ Spinal morphine
☐ other If other, please state____

4. Surgical blood loss ____________mLs

5. Tourniquet use ☐ Yes ☐ No

6. Duration of tourniquet ____________ mins

7. Duration of surgery ____________ mins

<u>Post-operative Variables:</u>

1. Use of Tranexamic acid ☐ Yes ☐ No

2. Use of wound drain ☐ Yes ☐ No

3. Initial analgesia
☐ LIA-intra-operative ☐ LIA- via intra-articular catheter ☐ single shot regional block
☐ ambulatory regional block ☐PCA ☐ other If other, please state
____

4. DOS mobilisation (marched on spot or greater) ☐ Yes ☐ No
If no, indicate reason (you may tick more than one box)
☐ pain ☐ inadequate return power/sensation ☐ nausea
☐ low BP ☐ dizziness ☐ RTW too late ☐ other
If other, please state ____

5. Post-op complications
☐ MERT call ☐ ICU admission ☐ DVT ☐ PE ☐ transfusion
☐ other If other, please state
____

6. Barriers to post-op progress (secondary complications)
☐ pain ☐ nausea ☐ drowsiness ☐ dizziness/low BP ☐ constipation
☐ delirium/impulsive ☐ anxiety ☐ quads inhibition ☐ other
If other, please state ____

7. Any attachments in situ after midday post-op Day 2 ☐ Yes ☐ No

Date of Discharge ____________ Length of Stay ____________ (nights on acute ward)

<u>Long Term Patient Reported Outcomes</u>

Oxford Hip or Knee Score ____________ EQ-5D VAS ____________

Version 1.4 20.05.18

Outcome Measures Record Patient Sticker

VAS assessed at each time point prior to assessment of Outcome Measures

TUG (Measured in secs)

Time Point	**Pre-op**	**Day 2**	**Day of D/C**
Trial 1			
Trial 2			
Walking aid used			

10mWT (Rolling start)

Time Point	**Pre-op**	**Day 2**	**Day of D/C**
Time (sec)			
Walking aid used			

Modified Iowa Level of Assistance Scale

Functional Task	Score (0)	Score (1)	Score (2)	Score (3)	Score (4)	Score (5)	Score (6)	Pre-op	Day 2	Day D/C
Supine to sitting on edge of bed	**Independent** No assistance or supervision is necessary to safely perform the activity (with or without and assistive device/aid).	**Standby** Nearby supervision is required; no contact is necessary	**Minimal** One point of contact is necessary, including helping with the application of the assistive device, getting legs on/off leg rest, and stabilising the assistive device	**Moderate** Two points of contact needed (1-2 people)	**Maximal** Significant support- 3 or more points of contact (>1 person)	**Failed** Attempted activity but failed with maximal assistance	**Not Tested** Test was not attempted due to medical reasons or reasons of safety			
Sit to stand	Independent	Standby	Minimal	Moderate	Maximal	Failed	Not Tested			
Walking	Independent	Standby	Minimal	Moderate	Maximal	Failed	Not Tested			
Negotiation of single step	Independent	Standby	Minimal	Moderate	Maximal	Failed	Not Tested			
Walking distance	>40m	26-40m	10-25m	5-9m	3-4m	2m	<2m			
Assistive device used	No assistive device	1 stick or crutch	2 sticks	2 elbow crutches	2 axillary crutches	Frame (hopper or 4WW)	Gutter/platform frame, standing lifter, hoist, or unsafe to use aid			
							Total Score			

Version 1.0 02/2018

Appendix XI: Enhanced Recovery Pathway (ERP) Discharge Criteria

The Wesley Hospital Enhanced Recovery Pathway Discharge Criteria for THA and TKA

Allied Health	-	Independent with transfers in/out of bed and chair
	-	Walking independently with aid
	-	Able to negotiate stairs (with supervision, if needed)
	-	Equipment and follow-up physiotherapy organised
Nursing	-	Showering
	-	Toileting (bowels opened)
	-	Pain adequately controlled
	-	Wound and dressings reviewed (as appropriate)
	-	Discharge Planning (e.g. services organised if applicable, support person contacted)
Patient	-	Accepting of discharge plan

Version 1.0 12/2015