Physical Activity Following Arthroscopy for Hip-Related Pain

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ABBREVIATIONS

ACL	Anterior cruciate ligament
ACLR	Anterior cruciate ligament reconstruction
ACL-RSI(sf)	Anterior Cruciate Ligament-Return to Sport after Injury scale (short form)
ANOVA	One-way analysis of variance
BMI	Body mass index
CI	Confidence interval
COREQ-32	COnsolidated criteria for REporting Qualiative research
COSMIN	COnsensus-based Standards for the selection of health Measurement Instruments
EPOC	Cochrane Effective Practice and Organisation of Care
ES	Effect size
FAI	Femoroacetabular impingement
FAIS	Femoroacetabular impingement syndrome
FORCe	Femoroacetabular impingement and hip OsteoaRthritis Cohort)
GRC	Global rating of change score
h	Hour
HAGOS	The Copenhagen Hip and Groin Outcome Score
HAGOS-PA	The Copenhagen Hip and Groin Outcome Score – Participation in Physical Activities subscale
HAGOS-SR	The Copenhagen Hip and Groin Outcome Score – Physical Function in Sport and Recreation subscale
HARP	Hip ARthroscopy Prospective Study
HHS	Harris Hip Score
HIP-RSI(sf)	Hip-return to sport index, short-form
HOOS	Hip Disability and Osteoarthritis Outcome Score
HOOS-SR	Hip disability and Osteoarthritis Outcome Score – Function in Sport and Recreation subscale
HOS	Hip Outcome Score
HOS-SS	Hip Outcome Score – Sport Scale
HSAS	Hip Sports Activity Scale
HUNT	Nord-Trøndelag Health Study questionnaire for the assessment of moderate to vigorous activity
Hz	Hertz
ICC	Intraclass correlation coefficient
iHOT-33	International Hip Outcome Tool
iHOT-33 SR	International Hip Outcome Tool –Sports and Recreational activities subscale
IHPRN	International Hip-related Pain Research Network

IPAQ	International physical activity questionnaire
I-PRRS	Injury-psychological readiness to return to sport scale
km	Kilometre
m	Meter
MAPE	Mean absolute percentage error
MCID	Minimal clinically important difference
MDD	Minimal detectable difference
mHHS	Modified Harris Hip Score
MIC	Minimal important change
NAHS	Non-Arthritic Hip Score
OA	Osteoarthritis
PARQ	Physical Activity Readiness Questionnaire
PASS	Patient-acceptable symptom state
PhysioFIRST	Physiotherapy for Femoroacetabular Impingement Rehabilitation Study
PROMs	Patient recorded outcome measures
PROSPERO	International Prospective Register of Systematic Reviews
PSFS	Patient-specific functional scale
RCT	Randomised controlled trial
SD	Standard deviation
SE	Standard error
SEM	Standard error of measurement
SPD	Standard paired difference
Tegner	Tegner Activity Scale
THA	Total hip arthroplasty
THR	Total hip replacement
™	Trademark
UCLA	The University of California at Los Angeles activity score

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ABSTRACT

Individuals undergoing arthroscopic hip surgery have high expectations for returning to physical activity to support their social roles, physical and mental wellbeing. The primary aim of this thesis was to investigate physical activity after hip arthroscopy surgery, assessed from several perspectives.

A systematic review, undertaken using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) framework, identified patient-reported improvements in physical activity following hip-arthroscopy; however, deficits were evident in achieving a level of improvement commensurate with an acceptable symptom state. Additionally, objective measures of physical activity were significantly under-represented in the available evidence. These findings indicated the need for more in-depth analysis to identify pertinent barriers and facilitators, both physical and psychological, to achieving a more satisfactory return to physical activity.

Investigation of the accuracy and utility of commercial accelerometers for measuring activity in young to middle-aged adults was undertaken in laboratory and free-living environments. Step count was the most accurate metric and also the most comparable metric between research- and commercial-grade devices and between generations of commercial devices.

Commercial accelerometers were used to compare step count between healthy controls and hip-related pain groups, including a group at one-year post-hip arthroscopy. No significant differences in step count between groups were identified after adjustment for age and sex; however, self-reported physical activity deficits remained apparent at one-year post-hip arthroscopy. Qualitative interviews identified barriers and facilitators, both physical and psychological, to achieving a more satisfactory return to physical activity. To support the assessment of psychological factors, a valid and reliable tool (Hip-Return to Sport after Injury (short form) was established to monitor psychological readiness to return to physical activity.

In conclusion, physical activity is a complex construct. Both objective and subjective measures are necessary to facilitate decision-making and address patient-specific barriers, facilitators and physical activity goals following arthroscopic hip surgery.

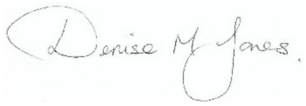
Key words: Hip, Arthroscopy, Physical activity, Outcomes, Activity trackers, Accelerometers, Fitness trackers, Psychological readiness, Qualitative, Rehabilitation.

STATEMENT OF AUTHORSHIP

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

The extent and nature of collaborative efforts are specified in full (page xviii-xxi). Each statement of collaborative input has been approved by all co-authors and their approval verified by Dr J. Kemp in the Authority to Submit Form. Although the publications involve joint authorship, I have made a significant and leading contribution to the work, equivalent to that expected for a traditional thesis. This thesis includes work by the author that has been published as described in the text. I am the primary author on the five published manuscripts presented in this thesis.

This thesis has been professionally proofread for spelling, grammar and punctuation by The Expert Editor, in accordance with the Guidelines for Editing Research Theses under the Australian Standards for Editing Practices.

Signed: 

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Jones, D., Crossley, K., Ackerman, I., Hart, H. and Kemp, J. Does the Fitbit Flex™ provide a reliable and feasible method of monitoring physical activity progression? Australian Physiotherapy Association Conference (Transform). 12th-19th October 2019. *Podium*

Blog Post

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PUBLICATIONS IN THIS THESIS

Copyright permissions for the following publications are presented in Appendix 1. For the purposes of assessment and examination, all five publications are presented, as published, as part of this thesis. To comply with copyright stipulations, as identified in Appendix 1, Study 2 (Chapter 5)[112] and Study 5 (Chapter 8)[113] will be redacted and replaced with the author manuscript, if accepted for inclusion in the La Trobe University Research Repository.

Jones, D. M., Crossley, K. M., Ackerman, I. N., Hart, H. F., Dundules, K. L., O'Brien, M. J., Mentiplay, B. F., Heerey, J. J. & Kemp, J. L. (2020). Physical activity following hip arthroscopy in young and middle-aged adults: A systematic review. *Sports Medicine-Open, 6*(7). https://doi.org/10.1186/s40798-020-0234-8

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Author Kay M. Crossley	Concept and design of research question, assisted in design of figures and tables, involved in manuscript preparation, project administration
Author Ilana N. Ackerman	Assisted in design of research question, preparation of tables and figures, manuscript preparation
Author Harvi F. Hart	Data analysis, preparation of tables and figures, manuscript preparation
Author Karen L. Dundules	Rated papers for quality appraisal, data extraction, involved in manuscript preparation
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Author Kate E. Webster	Research question, study design, conceptualisation of scale design, data interpretation, manuscript preparation
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Author Michael G. Pritchard	Research question, recruitment, manuscript preparation.
Author Joanne L. Kemp	Research question, study design, recruitment, data analysis, manuscript preparation, study administration.

Contributions by others to this thesis

L. Anderson and A. Clarke assisted with laboratory-based data collection and technical support.

M. Scholes, A. Rivers, R. Johnson, S. Coburn, M. King and J. Heerey assisted with data acquisition and management.

D. De Oliveira Silva assisted with infographics templates.

CHAPTER 1 : THESIS AIMS AND OVERVIEW

The overall aim of this thesis was to investigate physical activity after hip arthroscopy surgery, undertaken for hip-related pain.

Secondary aims were to 1) assess the functionality of a commercial activity monitor as a novel method of collecting quantitative activity data in a cohort of active young and middle-aged adults; 2) explore in-depth the factors impacting physical activity and return to physical activity following hip arthroscopy; and 3) establish a tool for the assessment of psychological factors associated with returning to physical activity following hip arthroscopy.

This mixed-methods research program incorporated subjective and objective outcomes, using quantitative and qualitative methodologies, in order to capture a broad range of perspectives across different aspects of physical activity.

The specific aims of the studies in this thesis were:

Study 1 (Chapter 3)

To systematically examine quantitative primary research to assess the impact of hip arthroscopy, undertaken for hip-related pain and dysfunction, on the physical activity of young and middle-aged adults. Additionally, an appraisal of the study outcomes aimed to provide an overview of contemporary physical activity outcome measures utilised in the research field.

Study 2 (Chapter 5)

To evaluate, in a laboratory setting, the validity of a commercial and a research-grade accelerometer (the Fitbit Flex™ and ActiGraph GT3X+) for measuring step count, including inter-device reliability of the commercial devices, at jogging and running speeds.

Study 3 (Chapter 6)

To establish the level of agreement between two generations of a Fitbit™ device (Flex™ and Flex 2™) for step count and activity minutes undertaken by healthy young to middle-aged adults in a free-living environment. Secondary aims were to evaluate the number of days of step count data retrieved from

the two grades of device over a two-week period and report the relative output of step count for the two grades of device in this cohort.

Study 4 (Chapter 7)

To (1) utilise commercial accelerometers to compare mean daily step count, a proxy measure for physical activity, in four groups of participants sited at different points on the spectrum of hip disease, from healthy controls to post-arthroscopy; (2) describe differences in hip-related quality of life between the symptomatic groups; (3) utilise commercial accelerometers to observe mean daily step count in people who were approximately three months, six months and one year post-hip arthroscopy; and (4) explore the limitations of collecting valid daily step count data for a) a single episode of data collection at baseline and b) repeated episodes of data collection.

Study 5 (Chapter 8)

To explore, using a qualitative approach, the factors influencing participation in physical activity for young to middle-aged adults at six months post-hip arthroscopy.

Study 6 (Chapter 9)

To determine the psychometric properties of a measure to assess psychological readiness to return to sport (the Hip-Return to Sport after Injury (short form)) in patients post-hip arthroscopy when returning to different levels of sporting and physical activity.

An overview of the thesis is presented in Table 1.1. The methods for each study are reported in each relevant chapter.

Table 1.1. Thesis overview.

PART	CHAPTER	STUDY
PART A: INTRODUCTION		
	Chapter 2: Introduction	
	Chapter 3:	Study 1 - Physical activity following hip arthroscopy in young and middle-aged adults: a systematic review.
PART B: OBJECTIVE MEASUREMENT OF PHYSICAL ACTIVITY		
	Chapter 4: Introduction to Part B	
	Chapter 5:	Study 2 - Validity and reliability of the Fitbit flex™ and Actigraph GT3X+ at jogging and running speeds.
	Chapter 6:	Study 3 - What is the agreement between two generations of commercial accelerometer in a free-living environment for young to middle-aged adults?
	Chapter 7:	Study 4 - A proof of concept study utilising step count to compare physical activity between surgical and non-surgical patients with hip-related pain and healthy controls.
PART C: READINESS TO RETURN TO PHYSICAL ACTIVITY AFTER HIP-ARTHROSCOPY		
	Chapter 8:	Study 5 - Mismatch between expectations and physical activity outcomes at six months following hip-arthroscopy: a qualitative study.
	Chapter 9:	Study 6 - Psychometric properties of the hip–return to sport after injury scale (short form) for evaluating psychological readiness to return to sports after arthroscopic hip surgery.
PART D: OVERALL DISCUSSION AND THESIS CONCLUSIONS		
	Chapter 10: Thesis summary, implications and conclusion	

PART A

INTRODUCTION

CHAPTER 2 : INTRODUCTION

The hip joint is the largest weight-bearing joint in the human body and it plays a vital role in locomotion and daily activities. A 'pain in the hip' can have far-reaching consequences for individuals, particularly in relation to physical activity. The hip joint's primary function is to transmit weight and forces from the axial skeleton to the lower limb. This is critical for physical activity and requires the synovial ball and socket joint to provide stability, allow movement and bear loads. Many structural elements (the deep acetabulum, labrum, strong joint capsule, associated ligaments and dynamic muscular supports) contribute to enabling the hip to fulfil these functional requirements. The structural and functional components exist not just within the hip, but also within the broader context of the individual person. Influences such as age, sex, body mass or connective tissue disorders have the potential to impact joint stability, movement and loading[24, 42, 116]. The psychosocial context of an individual also impacts loading patterns, associated with sport, work or social responsibilities, which can influence focal structural changes at the hip[95]. The following section will briefly outline the anatomy of the hip in relation to stability, movement and load-bearing.

2.1 FUNCTIONAL ANATOMY OF THE HIP JOINT

2.1.1 Stability

The architecture of the hip joint offers an inherent degree of stability. The acetabulum faces laterally, anteriorly and inferiorly, forming a hemispherical hollow which accommodates the femoral head (Figure 2.1) such that architectural stability of the joint is greater in weight-bearing. The acetabular rim is completed inferiorly by the transverse ligament and deepened by the acetabular labrum. In addition to its structural role, the labrum further contributes to stability by providing a sealing function, generating negative pressure within the joint and thus resistance to dislocation[145].

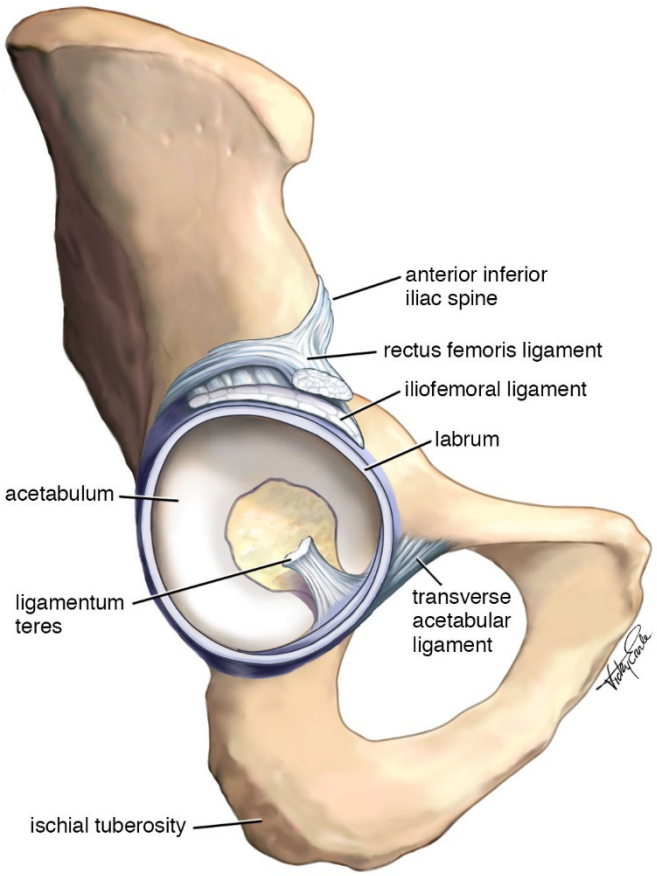

Figure 2.1. Transverse acetabular ligament, acetabular labrum and ligamentum teres (resected).

(Reproduced with permission of P. Brukner from the chapter "Hip related pain" in "Brukner & Khan's Clinical Sports Medicine: Volume 1: Injuries." 5th Edition; 2017 McGraw Hill, Sydney)[24].

In upright standing, the anterosuperior aspect of the femoral head becomes exposed, with the structure and function of the passive restraints of the hip (joint capsule and capsular ligaments) reflecting this. The strong fibrous capsule enclosing the hip joint and the majority of the femoral neck is, therefore, thicker anteriorly and superiorly[254]. Similarly, the three capsular ligaments (ischiofemoral, iliofemoral and pubofemoral; Figure 2.2) have the common function of resisting hip extension[24], their relative contribution varying in different ranges of flexion, extension and rotation[154, 176]. Neuroanatomy suggests a potential proprioceptive role for passive restraints such as the ligamentum teres, acetabular labrum and joint capsule[7, 75, 180], although their relative contribution to joint stability remains a subject of debate.

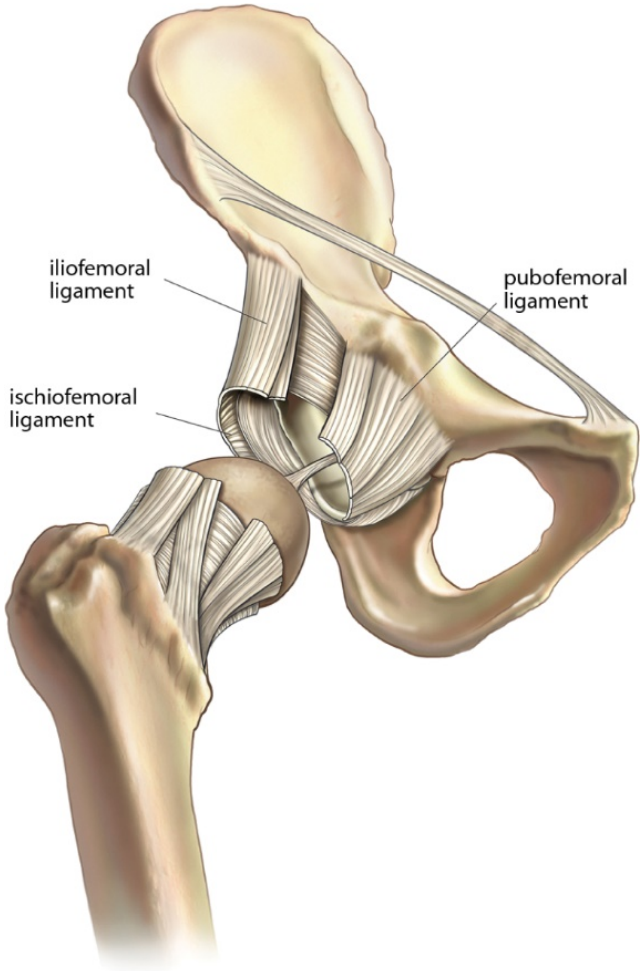

Figure 2.2. Capsular ligaments of the hip.

(Reproduced with permission of P. Brukner from the chapter "Hip related pain" in "Brukner & Khan's Clinical Sports Medicine: Volume 1: Injuries." 5th Edition; 2017 McGraw Hill, Sydney)[24].

Beyond these passive restraints of the hip, the overlying musculature plays a critical, and potentially modifiable, role in influencing the stability of the hip, particularly in the face of capsuloligamentous laxity. The integration of musculature around the hip (Figure 2.3) illustrates a complex, although not yet fully elucidated, dynamic relationship of muscle function supplementing the passive restraints of the hip.

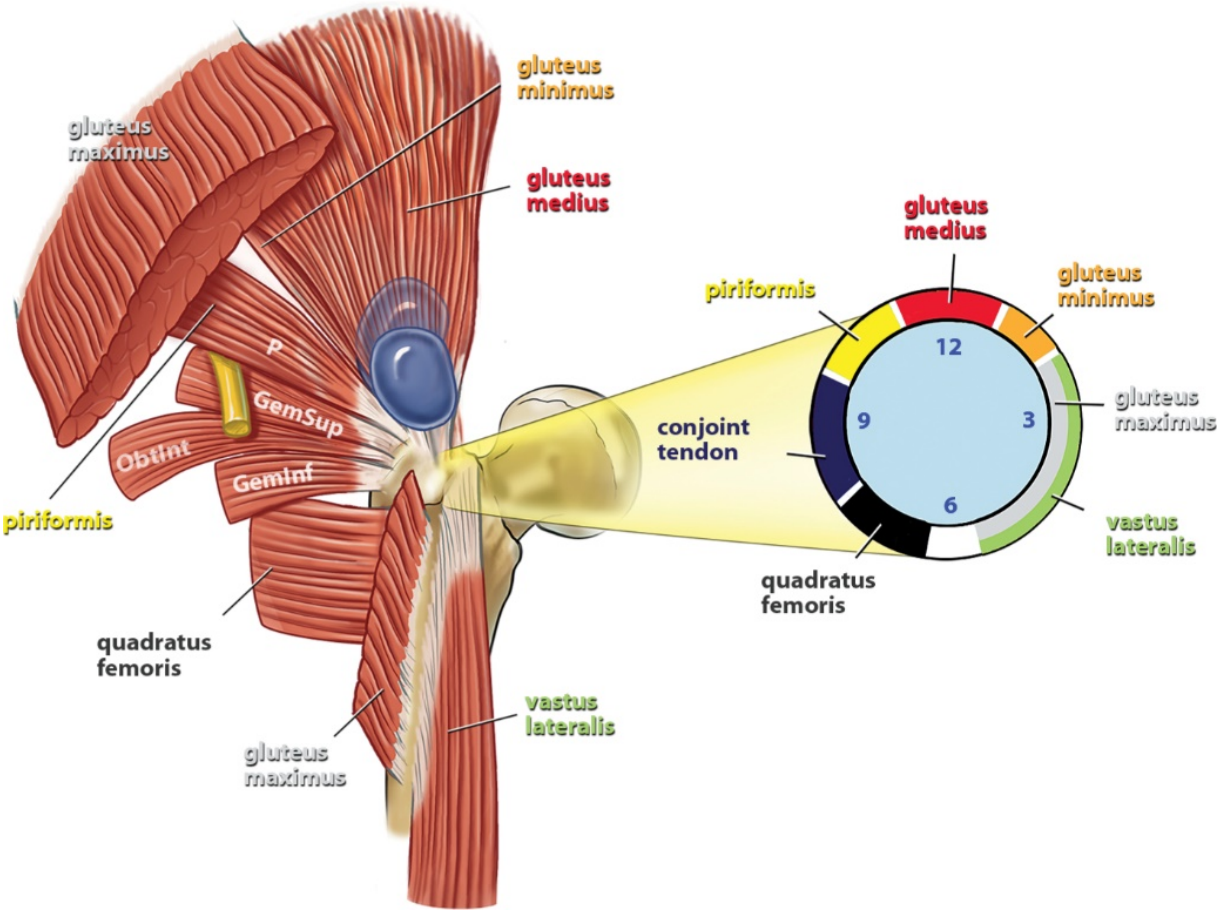

Figure 2.3. Muscle attachments around the greater trochanter of the femur.

(Reproduced with permission of P. Brukner from the chapter "Hip related pain" in "Brukner & Khan's Clinical Sports Medicine: Volume 1: Injuries: injuries." 5th Edition; 2017 McGraw Hill, Sydney)[24].

As the hip joint progresses through its range of movement, the line of action for specific muscles and, consequently, their function changes. The gluteus minimus, for example, has the potential to act as a flexor, abductor and internal or external rotator, depending on the position of the femur and which part of the muscle is active, alongside its role of stabilising the femur in the acetabulum[17, 254]. Other muscles that are biomechanically and physiologically suited to act as local stabilisers of the femoral head in the acetabulum include the quadratus femoris, gemelli, obturator internus and externus, iliocapsularis and possibly the deep fibres of iliopsoas[202]. The co-ordinated co-contraction of muscles acting as joint stabilisers may vary in relation to the speed, magnitude and direction of force applied as well as architectural variations in the joint. For example, muscles with the potential to support the anterior capsule, such as the iliocapsularis, may assume a greater stability role in individuals with compromised structural stability of the hip joint, despite this role not being evident in asymptomatic individuals[144].

2.1.2 Movement

As identified above, the factors affecting stability—architecture, passive restraints and muscle action— have a reciprocal relationship with the range of motion. The hip joint allows movement in all three planes. Factors affecting range of motion relate to joint structure, the relative laxity of passive restraints and those that result from repeated activity for work or leisure. Interplay exists between ranges in different planes; for example, the external rotation achieved by ballet dancers alters the spatial relationship between the greater trochanter and the acetabulum, enabling a greater range of abduction to be achieved[141].

Healthy articular cartilage plays a role in the smooth movement of the hip joint, providing a low-friction, lubricated surface[66]. The articular cartilage of the femoral head extends beyond the reaches of the acetabular rim to accommodate a full range of movement[28]. Cartilage is avascular, relying on nutrients from synovial fluid[177], which dictates that the movement and loading of the hip joint occurring during physical activity is essential to maintaining healthy cartilage structure[66, 249].

2.1.3 Load

Forces occurring at the hip are reported to be two to four times body weight in a single-leg stance, four- to six-times body weight during running, and seven times body weight when climbing stairs[101]. Muscles that span the hip, as well as muscles sited more distally in the kinetic chain (such as the vasti, soleus and gastrocnemius) contribute to loading at the hip joint during normal walking[41]. The distribution of these forces within the hip joint is mediated by synovial fluid and articular cartilage. Although the labrum bears minimal load in the normal hip, its role in the regulation of fluid transgression between the central and peripheral compartments of the hip influences the distribution of contact forces on the articular surfaces[54, 62].

Bone and cartilage are mechanosensitive and can adapt to alterations in load. The cyclical loading of the hip joint, experienced during weight-bearing activity such as walking, is essential for cartilage health. As an avascular structure, cartilage relies on diffusion for nutrient supply. Thus, cyclical loading affects the rate at which chondrocytes receive nutrients, particularly the movement of large solutes that significantly influence cell metabolism[177]. Diminished cyclical loading, where load-bearing activity has been reduced, results in disuse atrophy of cartilage[249]; however, the reduced synthesis of proteoglycan associated with disuse atrophy can be reversed with the resumption of load-bearing activity[253].

Similarly, bone remodelling is a lifelong process due to the balanced activity of osteoblasts, the bone-forming cells, and osteoclasts, the bone-resorbing cells. Bone shape, mass and strength are

influenced by load[60]. Correlations exist between load and bone density, with greater bone mineral density being evident in the hips of athletes participating in high-impact activities compared to athletes participating in low-impact activities[247]. In the mature skeleton, joint loading is influential in maintaining bone density[18]. The maintenance of appropriate weight-bearing physical activity, and therefore the loads applied, can affect hip health across the lifespan and may influence the risk of hip fracture in later life[16].

2.1.4 Implications of morphological variations of the hip joint

The above information relates to the structure and function of the 'textbook' hip joint which can potentially be impacted by morphological variations in multiple ways. For example, the depth and orientation of the acetabulum affect the relative coverage of the femoral head. A more vertically orientated acetabulum is associated with reduced coverage of the femoral head[101] and has implications for reduced joint stability. Global or focal over-coverage of the femoral head by the acetabulum, or pincer morphology[79], conversely has the potential to limit movement through earlier abutment of joint surfaces, as can flattening or convexity of the head/neck junction of the femur (cam morphology)[73]. Such architectural variations impact on areas of loading through the hip joint and altered function of soft tissue restraints. For example, indications are that loads on the labrum are low in the normal hip, but its role in load-bearing is increased in less stable hips with a shallow acetabulum[94]. Where altered loading or impingement of the labrum precipitates labral tears, the seal function and thus fluid transgression may be compromised[54, 63].

2.2 PHYSICAL ACTIVITY

2.2.1 Definition

At a fundamental level, physical activity can be defined as a bodily movement produced by skeletal muscles that results in energy expenditure[32]. The term is also commonly used to signify 'health-enhancing physical activity'[227], implying activity with a greater level of energy expenditure. Physical activity can encompass any aspect, or dimension, of activity taking place across different lifestyle domains (Figure 2.4).

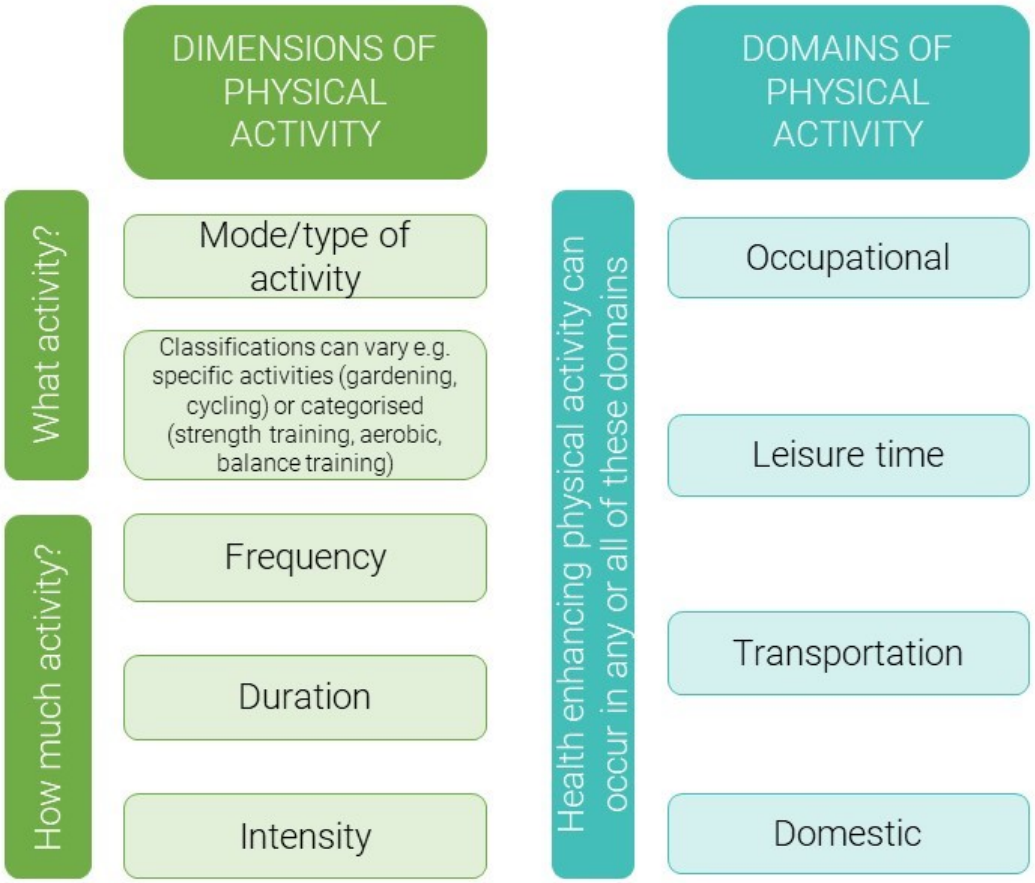

Figure 2.4. Dimensions and domains of physical activity (adapted from Strath et al., 2013)[227].

Within the context of this thesis, to maintain relevance to a cohort who potentially have high demands in all the domains identified in Figure 2.4, physical activity is deemed to be activity exceeding that required for normal activities of daily living (i.e., activities required for normal self-care including locomotion, dressing, personal hygiene and feeding[55]), including recreational exercise and sport. Sport is interpreted in a wider community context[65], inclusive of competitive, non-competitive, structured and unstructured recreational leisure-time physical activity.

2.2.2 Measurement of physical activity

Physical activity involves the complex interaction of structured and unstructured daily activity, presenting a challenge as to how this can be effectively quantified.

2.2.2.1 Subjective assessment of physical activity

Subjective, self-reported measures of physical activity can be used to estimate the quantity of activity undertaken. These measures are frequently employed to estimate physical activity in large population studies and global activity surveillance[51]; however, it is known that differences exist

between subjective, self-reported, quantified activity and objective measures such as accelerometry[118, 193]. Vaughn, Dunklebarger, and Mason (2019) reported mean errors in activity estimation of more than 90% in patients following hip or knee arthroplasty, while vigorous physical activity, as may apply to young and middle-aged adults, has shown particular susceptibility to over-reporting by fitter individuals[236]. Although subjective measures can capture information from different dimensions and domains of physical activity, the inherent biases introduced through individual recall, culture and compliance highlight the advantages of also assessing objectively measured physical activity.

Population-specific patient-reported outcome measures (PROMs), such as those identified in Table 2.1, can be used to apply further context to the assessment of physical activity, offering information as perceived by the individual. In addition to the dimensions and domains identified in Figure 2.4, PROMs can be used to explore perceptions of physical activity and its relationship with pain, symptoms and quality of life. The discrepancies identified above in self-reported and objectively measured physical activity illustrate that perception of change in physical activity, as captured in PROMs, may differ from objectively measured change. In a review of surgical outcome reporting for patients with FAI syndrome, it was recognised that less than 25% of studies documented patients' sport or work related abilities and that more than 15 different patient reported outcome measures were utilised across studies[200]. Recent recommendations[105] identify The Copenhagen Hip and Groin Outcome Score (HAGOS)[230]and the International Hip Outcome Tool (iHOT)[82, 168] as the most appropriate for young and middle-aged active adults with hip-related pain. However, high error scores for the iHOT indicate the need for caution when using the scale to measure change for individual patients in a clinical setting. Questions remain over the applicability of PROM's in different contexts, such as in surgical or non-surgical settings; establishing appropriate psychometric properties of the PROM's for young and middle-aged adults with hip-related pain is an ongoing process, particularly in relation to content and structural validity[105]. As identified in Table 2.1, different PROM's evaluate different dimensions of physical activity and quality of life. A single PROM is unlikely to capture all aspects of physical activity and the use of multiple PROM's adds to the burden of patients in clinical practice and research settings.

The International Hip Outcome Tool (iHOT-33) was developed to measure health-related quality of life in young, active patients with hip disorders[168]. The tool contains 33 questions, covering four domains (symptoms and functional limitations; sports and recreational activities; job-related concerns; and social, emotional and lifestyle concerns) with numeric scores ranging from 0 (worst quality of life) to 100 (best quality of life). The tool has adequate psychometric properties for young people following hip arthroscopy[123, 168] and those with hip-related pain[96, 105]. This outcome measure has been used in a recent meta-analysis of data from randomised controlled trials, comparing

surgical and conservative management of femoroacetabular impingement (FAI) syndrome[31] to provide a common point of comparison; it is identified as one of the most appropriate tools for the cohort in this thesis[105].

Table 2.1. Examples of patient-reported outcomes measuring different dimensions of physical activity.

DIMENSION OF PHYSICAL ACTIVITY	NAME OF PATIENT REPORTED OUTCOME	SUBSCALE (WHERE APPLICABLE)	SCORING	RECALL	PSYCHOMETRIC PROPERTIES ESTABLISHED FOR HIP	RECOMMENDED POPULATIONS
Hip related symptoms and quality of life	International Hip Outcome Tool (iHOT-33)		Composite score (%), 0=significantly impaired, 100=no problems	Previous month	Yes	Active adults (18-60) with symptomatic hip conditions [123, 168].
Ability to perform physical activity.	Hip Disability and Osteoarthritis Outcome Score (HOOS)	HOOS – function in sport and recreation	Separately scored subsection (%). 0=extreme disability; 100=no symptoms	Previous week	Yes	Adults with hip disability with/without OA[123, 133].
	Hip Outcome score (HOS)	HOS -sports scale	Separately scored subsection (%). 0=unable to do; 100=no difficulty at all	Previous week	Yes	Adults with hip labral tear and following arthroscopy[123, 155-157].
	The Copenhagen Hip and Groin Outcome Score (HAGOS)	HAGOS – physical function in sport and recreation	Separately scored subsection (%). 0=extremely problematic; 100=no problems	Previous week	Yes	Active adults (young-middle aged) with hip and groin pain; Arthroscopy[123, 230].
		HAGOS – participation in physical activity				
	Patient-specific functional scale (PSFS)		Patient nomination of activity. For each activity 0-10 scoring (0=unable to perform activity; 10=able to perform at pre-injury level)	Current status	No	Adults – musculoskeletal conditions[99, 226].
Activity level	Hip sports activity scale HSAS		9 sports activity levels. Single score: 0=no sport; 8=elite (highest hip load)	Current status	Yes	Femoroacetabular impingement ǂsyndrome[175].
	Tegner Activity Scale (Tegner)		11 levels of sport and physical activity (including work) 0=sick leave; 10=international elite	Current status	No	Adults following knee ligament injury[229].
Quantifying physical activity	Nord-Trøndelag Health Study questionnaire for assessment of moderate to vigorous activity (HUNT).	Physical activity intensity, frequency and duration (3 items)	Single summary score		No	Adults[140].
	International physical activity questionnaire - short form. (IPAQ-short)		Duration spent undertaking different levels of activity – [walking, moderate, vigorous]. Total score=Median METs mins/week	Previous week	No	Adolescents and adults (15-69)[43].
Psychological preparedness	Injury-psychological readiness to return to sport (I-PRRS) scale	Whole scale (6 items)	Single composite score (<20=low overall confidence to return to sport; 60=utmost confidence to return to sport)	Current status	No	Collegiate athletes[77].
	Hip-return to sport index (HIP-RSI). Hip-return to sport index, short-form (HIP-RSI(sf))	Whole scale (12 items or 6 items)	single composite score (0=extremely negative psychological responses; 100=no negative psychological responses)	Current status	No	Adults following hip arthroscopy[266].

ǂaddition to original text; MET= Metabolic Equivalent

2.2.2.2 Objective measures of physical activity

Total energy expenditure provides an overall assessment of the energy cost of activity to an individual, but the objective and accurate assessment of this relies upon sophisticated equipment and expertise. Within a laboratory setting, indirect calorimetry can be used, while in free-living or unstructured activity settings, doubly labelled water, requiring the collection and analysis of stable isotopes in urine, is the gold standard. Neither of these methods are practical within clinical practice.

A less rigorous alternative is available in the form of wearable monitors. Providing objective measures of physical activity, they can be split into six main types: pedometers; load transducers/foot-contact monitors; accelerometers; heart rate monitors; combined accelerometer and heart rate monitors; and multiple sensor systems[26]. Wearable monitors vary in cost and sophistication, having the potential to measure a variety of metrics including step count, acceleration, global positioning, heart rate, and skin temperature. A wide variety of devices are used in research, with cost burdens varying from $US25 to $US4,500[220]. A further division can be made between research-grade monitors and commercial, consumer-wearable devices/activity trackers. Research-grade monitors require a degree of expertise to use and access to analysis software packages. Commercial devices are more 'user-friendly', with data easily accessible to the individuals using the device. In recent years, the commercial market has seen a dramatic influx of wearable devices. The extent and pace of growth are evidenced by an assessment of the consumer-wearables market[71] which identified over 300 devices targeting a variety of health-related outcomes, over 200 of these relating to physical activity outcomes. The production and use of wearable devices continue to increase[225], providing an attractive alternative for researchers collecting physical activity data due to their consumer-acceptability, competitive pricing and availability. A recent review identified 14 different activity monitors used in research relating to hip and knee osteoarthritis (OA), the majority of which were research-grade devices[220]. In the wider field of hip-related research, this trend continues; objective assessment of physical activity is predominantly undertaken with older adults undergoing hip arthroplasty and utilising research-grade devices[57, 98, 108, 149, 159]. Two studies undertaking objective activity monitoring in younger surgical cohorts[107, 131] have also used research-grade devices and the potential use of commercial devices for young to middle-aged adults with hip-related pain remains untested. Fitbit™ (Fitbit Inc., San Francisco, CA) devices, as one of the brands dominating the commercial market[225], have so far only been used successfully to monitor physical activity in populations with a relatively low step count, undergoing knee[243] and hip arthroplasty[237].

2.3 HIP-RELATED PAIN

2.3.1 Definition

Although a precise definition of hip-related pain is becoming clearer[199], the diagnosis and management of hip-related pain remain challenging due to the potential range of structures involved, discordance between diagnostic tests and symptoms and the frequency of concurrent problems[79, 92, 93, 199, 257, 262]. Several consensus meetings have taken place in recent years, during which time definitions have evolved (Figure 2.5). Hip-related pain was one of five entities agreed upon in an athlete-focused consensus of classifications for groin pain[262], alongside pubic-related, inguinal-related, iliopsoas-related and adductor-related groin pain. As these classifications imply, hip-related pain is associated with intra-articular hip joint structures, as opposed to extra-articular. At the 2018 International Hip-related Pain Research Network (IHPRN) consensus in Zurich[199], further recommendations on the definition of hip-related pain were agreed to include femoroacetabular impingement (FAI) syndrome, acetabular dysplasia/hip instability and labral, cartilage and ligamentum teres conditions occurring in the presence or absence of altered bony morphology. The Warwick Agreement[79] expands this framework, further defining FAI syndrome. The definition of hip-related pain for young and middle-aged adults used in this thesis aligns with the recommendations of the IHPRN consensus[199].

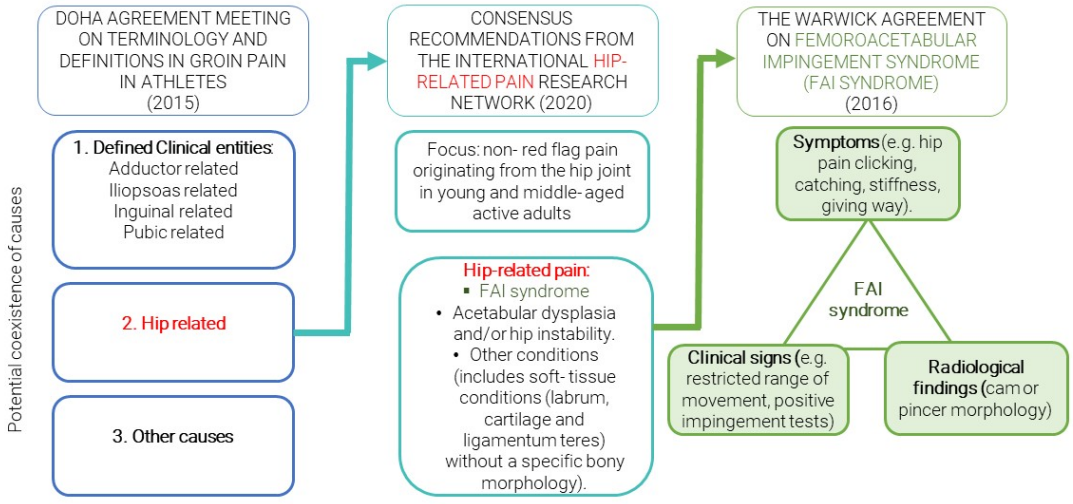

Figure 2.5. Definitions of hip-related pain through consensus of expert opinion. Adapted from Weir et al. (2015)[262], Reiman et al. (2020)[199] and Griffin et al. (2016)[79].

2.3.2 Prevalence of hip-related pain

Given the differing definitions, variability exists in how the prevalence of hip-related pain is reported; the true proportion of the population with hip-related symptoms is difficult to extrapolate from the current evidence. Categorising hip and groin pain as a single entity, 49% of male sub-elite footballers report symptoms, with 31% reporting symptoms of hip and groin pain lasting more than six weeks[232]. Similarly, 44% of female sub-elite football players report hip and groin injury within a season, the majority not being associated with time lost from play[142]. In cohorts of professional male football players, hip and groin injuries resulting in time lost from play constituted 14% to 18% of all reported injuries[172, 263]; however, the majority of these hip and groin injuries were classified as extra-articular, such as an adductor-related injury. An earlier review of groin injuries in elite team sport noted a trend of increased reporting of hip-joint related symptoms in contact sports, such as Australian Rules Football[182], not reflected in these studies of football (soccer) players, highlighting questions about how symptoms are understood, categorised and reported. The true proportion of young and middle-aged adults suffering from hip-related pain in the general population is unclear. Where efforts have been taken to differentiate hip-related pain (intra-articular) from other presentations of longstanding (>3 months) extra-articular groin pain for patients attending tertiary clinics, approximately 50% of the presentations were classed as hip-related in nature[143, 185]. At a general population level, evidence from a cross-sectional population-based study in the Netherlands indicates a point prevalence of hip pain of approximately 4% for men and 6% of women aged 25-44 years[189].

2.3.3 Aetiology of hip-related pain

Hip OA is commonly characterised by pain, restricted range of movement and reduced physical function[6]. Hip OA is associated with structural changes such as hypertrophy of the bone (osteophytes and subchondral bone sclerosis), joint space narrowing and thickening of the capsule[33]; it represents a large proportion of the global osteoarthritis burden[210]. Hip-related pain may be associated with OA and represent an early stage on the continuum from early to more severe hip-joint disease (Figure 2.6). Morphological changes of the femoral neck (cam morphology) have been linked to the incidence of hip-related pain[130] and, when associated with FAI syndrome, possibly the progression of OA over time[3, 136, 217]. Despite these proposed associations, a cross-sectional comparison of football players (sub-elite soccer or Australian football) identified the presence of cam morphology in players both with and without hip pain (71% and 63% respectively), indicating that cam morphology may not be the primary driver of symptoms [91]. Intra-articular hip pathologies identified by imaging, such as labral tears and chondral defects, are evident in both symptomatic and asymptomatic individuals and therefore their contribution to hip-related pain is unclear. Labral tears were identified in 69% of asymptomatic individuals between 16 and 66 years

of age and chondral defects were identified in 24% of the same cohort[197]. A recent systematic review identified a similar prevalence of labral tears in individuals with and without pain (62% and 54%, respectively) but a higher prevalence of chondral defects in symptomatic individuals (64%) compared to 12% in asymptomatic individuals[93]. Extrinsic factors also have a potential role in symptom presentation. In individuals with FAI syndrome, higher body mass index (BMI) correlated with increased pain scores and acetabular cartilage damage[78]. The complex relationships between pain presentation, imaging findings and response to physical activity will be even less predictable when hip-related pain becomes chronic [45, 170, 222].

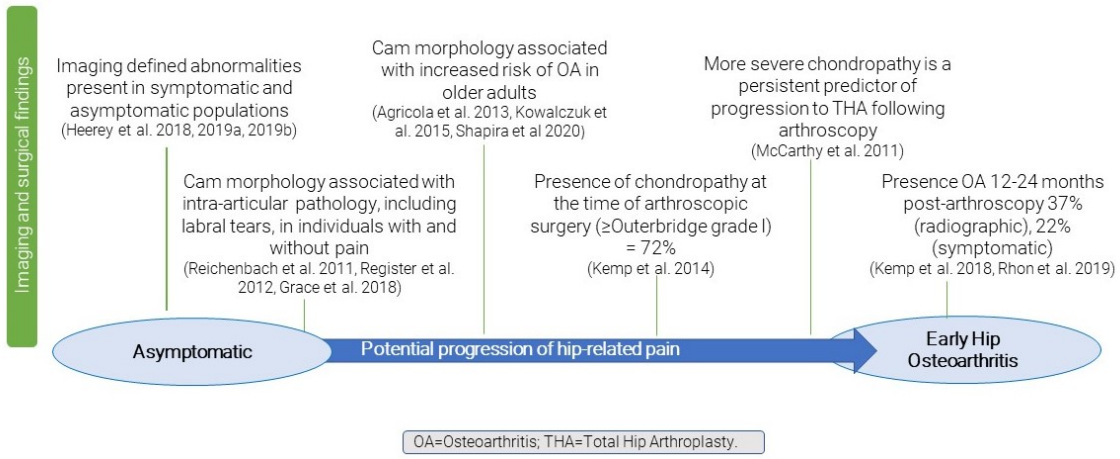

Figure 2.6. The potential continuum of hip-related pain to early hip osteoarthritis; imaging and surgical findings[3, 78, 91-93, 124, 126, 136, 162, 197, 198, 204, 217].

Early chondral changes are thought to be one of the earliest detectable signs of OA[194]. Although similar to other features, the relationship with pain is unclear[92], despite the indications that chondral defects are frequently associated with pain[93]. More advanced chondral changes, such as full-thickness lesions[47], are predictive of total hip arthroplasty (THA) following previous arthroscopic intervention[162]. The incidences of both radiographic and symptomatic OA increase with age[246, 252]; however, the exact sequelae of events has yet to be established. It is likely to be a complex interaction of mechanical alterations to focal stresses and inflammatory mediators[19, 38, 255] that contribute to the presentation of symptoms and progression to OA, with the specific role of physical activity remaining unclear[20]. The relationship of hip-related pain and physical activity is discussed further in section 1.3.5.

2.3.4 Burden of hip-related pain

While the true prevalence of hip-related pain in young to middle-aged adults is unknown, the burden of hip-related pain, at a time of life associated with considerable work, family sporting, or recreational commitments, can be high (Figure 2.7). When considering responses to the Hip

Osteoarthritis Outcome Score (HOOS) as a reflection of burden across multiple domains, respondents seeking treatment for hip and groin pain indicative of FAI syndrome[96] and respondents awaiting hip arthroscopy[69] identify impairments in sport and recreational activities similar to, or worse than, older respondents[228] or respondents with primary hip OA[181]. Quality of life responses for young to middle-aged adults with hip-related symptoms show greater impairments than both older individuals and individuals with OA. As illustrated in Figure 2.7, responses to the HOOS at one-to-two years post-hip arthroscopy indicate ongoing impairments in comparison to healthy controls, particularly in relation to sport and recreational activities and quality of life.

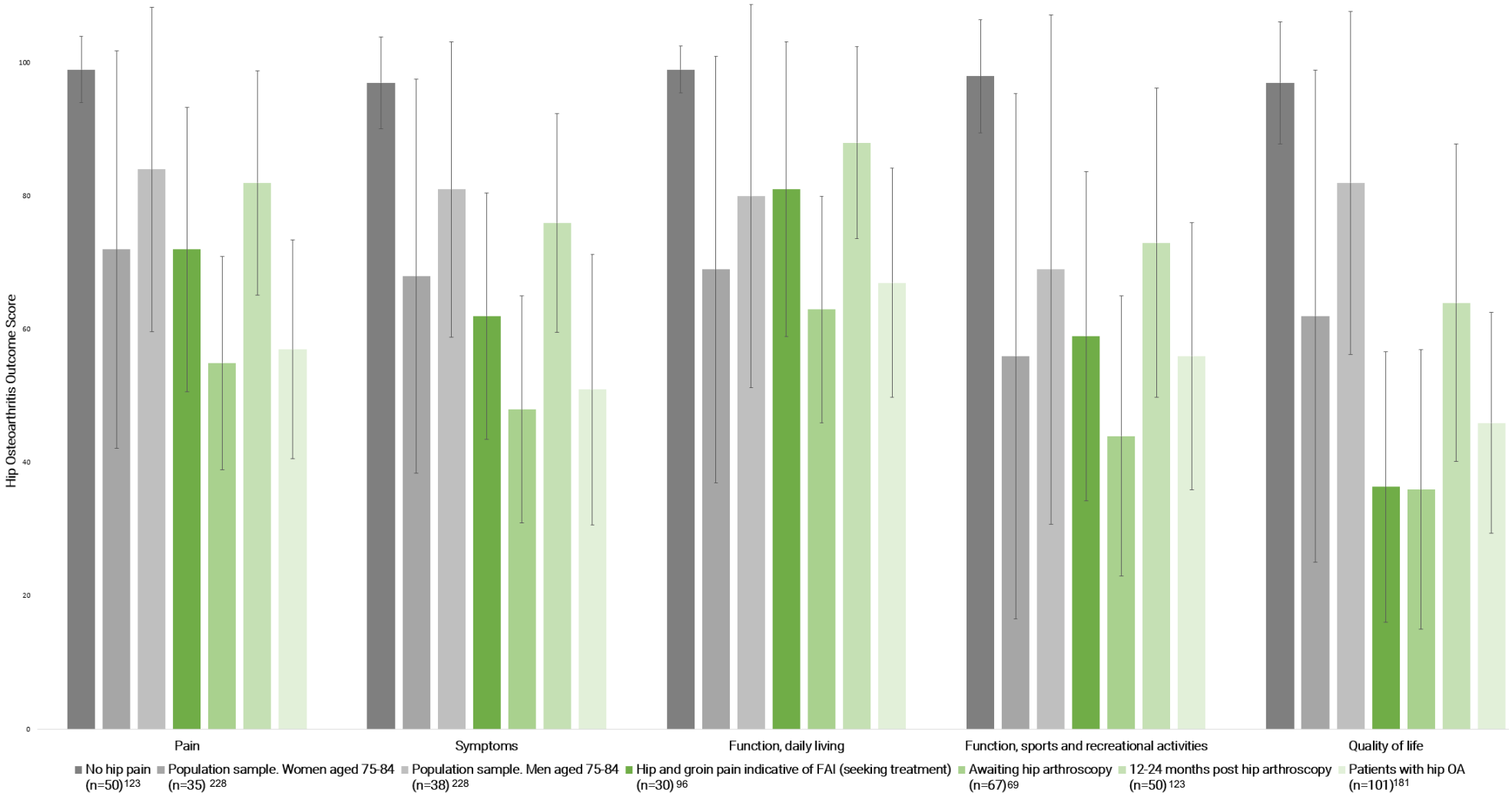

Figure 2.7. Comparative responses to the Hip Osteoarthritis Outcome Score (HOOS) across various studies in a selection of groups, representing a continuum from no hip pain to patients with hip osteoarthritis (OA). Adapted from Kemp et al. (2013)[123], Sundén et al. (2018)[228], Hinman et al. (2014)[96], Freke et al. (2019)[69] and Olsen et al. (2020)[181]. Error bars show standard deviation.

2.3.5 Hip-related pain and physical activity

For those suffering from hip-related pain, maintaining cardiovascular fitness and muscle strength becomes more challenging due to the weight-bearing nature of many physical activities and pain associated with specific movements or postures within sporting activity. Persistent hip-related pain may lead to physical activity avoidance with subsequent impacts on mental and physical health[48]. A decline in activity has been identified prior to hip arthroscopy[25, 76], with consistent reductions described across a range of activities including cycling[68], swimming[67], running[146], high-intensity interval training[206], golfing[258] and dancing[245] (Figure 2.8).

The relationship between physical activity and the progression of hip-related pain may have positive and negative associations, being both potentially protective and provocative (Figure 2.8). Physical impairments, such as reduced muscle strength, decreased range of movement and performance of functional tasks, were evident in hip-related pain and post-arthroscopic populations[70, 85, 86, 121, 129]. Physical impairments have implications for an individual's ability to undertake physically active tasks and provides a point of focus for rehabilitation. Placing aside the wider health implications of maintaining an active lifestyle, it is known that joint loading, associated with weight-bearing activity for the hip, is essential for joint health[34, 173]. However, assessment of total lifetime physical activity exposure found higher levels of physical activity to be associated with hip-related pain in young and middle-aged adults, both with and without cam and/or pincer morphology[135], implicating loading over morphology as a possible contributing factor. Similarly, exposure to high physical demands in the workplace and prolonged sitting have been identified as risk factors in hip-related pain[191], illustrating the complex relationship between symptoms and physical activity or inactivity.

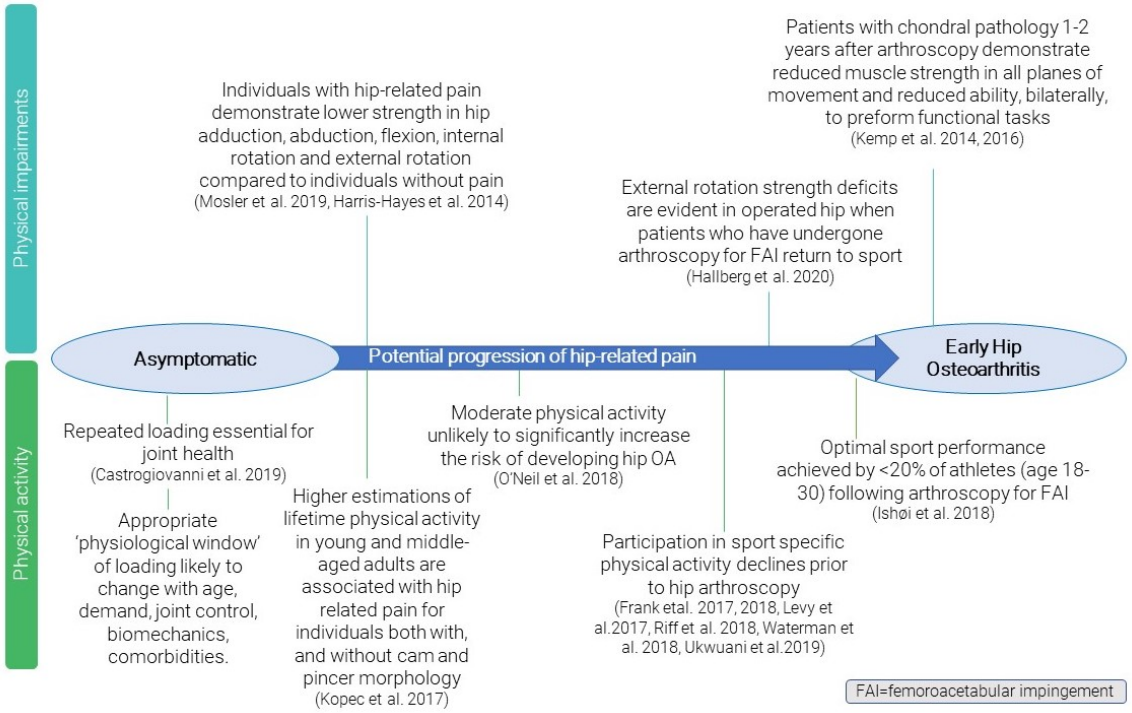

Figure 2.8. The potential continuum of hip-related pain, physical impairments and physical activity[34, 67, 68, 85, 86, 106, 121, 129, 135, 146, 171, 178, 206, 245, 258].

If we consider risk factors for the progression to hip OA, the role of physical activity remains unclear. Population-based prospective cohort studies have found no measure of physical activity exposure to be related to an end-point of total hip replacement (THR)[256] and no association between leisure-time physical activity and the incidence of severe hip OA[2]. A potentially protective role of leisure-time physical activity was identified for older women in relation to progressing to THR[2] whereas higher levels of leisure-time activity in women aged ≤45 years were identified as a potential risk factor for THR in later life[109]. These findings indicate that age, or time of life, is relevant when considering the potential positive or negative effects of hip joint loading related to physical activity. The domain in which physical activity occurs (Figure 2.4) may also be a relevant factor. Heavy work-related physical activity has been identified as predictive of the occurrence of hip OA, while leisure-time physical activity has not[115]. An elite/professional level of involvement in some sports may increase the risk of hip OA[187, 251]; however, it is difficult to isolate exposure to injury from exposure to physical activity. It should be noted that the lack of consistent conclusions in studies aiming to identify causative links may relate to heterogeneity in the studies, such as in how hip-related pain or OA are defined, the methods of activity data collection employed and confounding factors such as exposure to injury and the age of participants at baseline.

While the positive role of physical activity in the management of established arthritic change is endorsed[104, 137], the role of physical activity in relation to hip-related pain and early joint changes

in the younger population undergoing arthroscopic hip surgery, remains ambiguous. Despite the complexity of interactions associated with hip-related pain, management principles aim to reduce short- and long-term impact at both an individual and societal level. The most effective methods of achieving this are yet to be identified. There is a need to investigate modifiable factors, such as physical activity, and optimise their potential role in short- and long-term management.

2.3.6 Management of hip-related pain

Hip-related pain may have different, or multiple, underlying pathologies with varying presentations of disability. Consequently, management options will vary for individuals and along the continuum of disease/hip pain, with the best time and method of intervention to minimise progression of symptoms remaining uncertain. Management options may be non-surgical (such as physiotherapist-led treatment, exercise-therapy, pharmaceuticals and joint injections) or surgical[128]. Evidence for the effectiveness of non-surgical management options, particularly in relation to physical activity related outcomes, is limited in the current literature[127]. In a study following the progression of participants with pre-arthritic, intra-articular hip disorders through three phases of treatment[103], 44% were satisfied with the results of non-surgical treatment and did not chose to escalate treatment options and pursue surgical intervention. Access to a variety of surgical and non-surgical options are recommended in guidelines for the treatment of FAI syndrome[79] although no clear recommendations are made for non-surgical treatments to be the first-line option of care. Private and public healthcare systems within different countries are likely to host different treatment pathways. A North American study[23] highlighted that 21% of patients with FAI syndrome did not believe physiotherapy or anti-inflammatories would help their symptoms, with the same percentage unwilling to try conservative treatment measures for six months prior to surgery. Where surgery and physiotherapist-led interventions have been directly compared, findings are equivocal. Using the iHOT-33 to provide a measure of hip related quality of life, a comparison of hip-arthroscopy and a personalised hip therapy protocol identified an adjusted estimate of treatment effect of 6·8 points out of 100 (95% confidence interval 1·7 to 12·0, p=0·009) in favour of the hip arthroscopy intervention 12 months after randomisation[81]. From a more specific physical activity perspective, at six-months post randomisation, greater improvements in the Hip Outcome Score (HOS (sport subscale)) were evident for surgical patients than for patients attending a maximum of eight physiotherapy sessions (adjusted treatment effect (mean difference adjusted for sex, age, baseline activity of daily living score, and site) of 11.7 points out of 100 [95% confidence intervals 5.8 to 17.6])[184]. Conversely, a study undertaken in a military setting[153] found no difference in the HOS (sport subscale) at six months (A between group difference of 9.1 points out of 100 [95% confidence intervals -7.8 to 26.1]) following surgery or physiotherapy management. A high crossover rate from physiotherapy to surgical treatment was

evident in these military personnel (70%)[153] compared to the RCT undertaken in a UK community setting (7%)[184]. This is possibly indicative of unique physical activity demands in a military cohort, reflecting previous indications that subjects with higher baseline activity scores are more likely to choose surgery[103].

The focus of this thesis is on individuals receiving surgery and, specifically, hip arthroscopy. The largest body of research evidence regarding management of hip-related pain in young and middle-aged adults is weighted toward arthroscopic surgical intervention; however, considerable heterogeneity exists between studies in many aspects, including diagnoses[122], intervention[205] and outcome measures[200]. Preliminary evidence from three recent randomised controlled trials suggests that hip arthroscopy, undertaken to treat FAI syndrome, may provide small to moderately superior outcomes compared to non-surgical treatment [31, 80, 153, 184], but at much greater cost[81], carrying a risk of adverse events such as neuroparaxia, infection and heterotrophic bone formation[122, 205].

Hip arthroscopy is a surgical procedure that aims to alter intra-articular structures thought to be associated with symptoms. Structures commonly targeted in surgery are the labrum, altered bony morphology of the femoral neck junction and/or acetabulum; chondral defects, and tears of the ligamentum teres (Figure 2.9), all of which may be apparent in both symptomatic and asymptomatic individuals. The potential association between cam morphology of the femoral neck and OA has led to the practice of 'hip-preservation surgery' for patients with FAI syndrome, whereby procedures are undertaken to prevent or decelerate OA changes. The efficacy of surgery in relation to this aim is unclear[50, 215], with no long-term studies, to date, reporting the development of OA as a comparative feature between surgical and non-surgical interventions; however, the presence of radiographic OA has been noted in 37% of hips in a cohort 12 to 24 months post-arthroscopy[124] and an incidence of 22% of patients with symptomatic OA 24 months post-arthroscopy[204] was also identified.

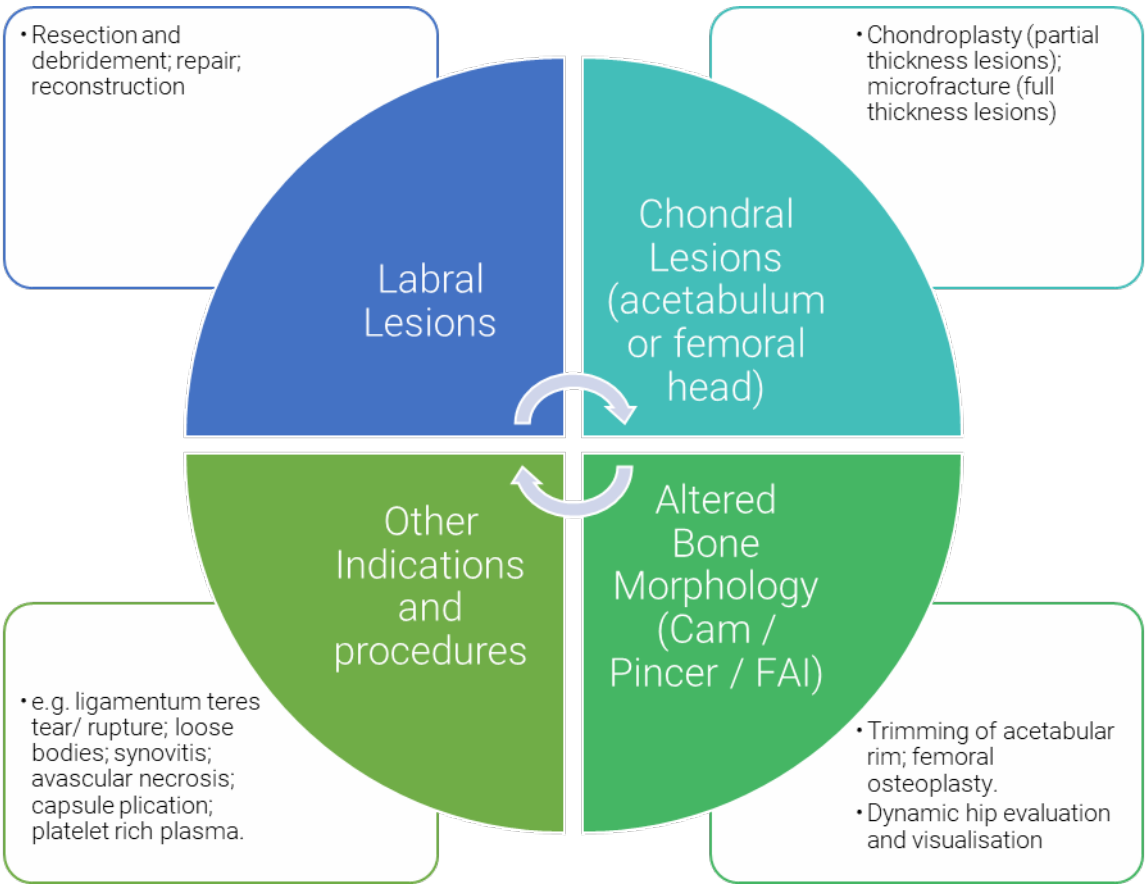

Figure 2.9. Hip arthroscopy, summary of indications and procedures (adapted from Byrd (2006); Ellis et al. (2011)[27, 56]).

If trends in arthroscopic hip surgery are extrapolated as an indicator of the number of young and middle-aged adults seeking a surgical solution for hip pain, a startling picture is presented. A 365% increase in the rate of hip arthroscopy between 2004 and 2009 in the USA[169] has been cited and a larger increase of 727% for hip arthroscopies performed in the UK between 2000 and 2013[183]. Confirming the same picture of rapid growth, insurance data from the USA indicates 1.6 cases per 10,000 orthopaedic patients underwent hip arthroscopy in 2007 compared with 4 per 10,000 in 2011[218]. Similarly, arthroscopy procedures increased significantly from 3.6 per 100,000 in 2005 to 16.7 per 100,000 insurance enrollees in 2013 (age-standardised and sex-standardised rates)[139]. More recent figures pertaining to Finland[119] also identify a five-fold increase between 1996 and 2013; however, 2013 represented the peak rate of hip arthroscopies undertaken in Finland, with a subsequent yearly decline of approximately 18% through to 2018. This mirrors the trajectory seen previously with knee arthroscopies, as the knowledge base underpinning risks and limited benefits associated with surgery grew[100]. Indications are, that the average patient is in their mid- to late-thirties, with more females than males undergoing surgery[49, 150, 200, 223]. These data underpin the premise that individuals undergoing hip arthroscopy are a young cohort with concomitant work, family and social responsibilities. Attaining the physical capacity to maintain these roles is

key in pre- and post-operative management, with the need to identify and quantify activity-related measures of importance to this expanding patient group.

2.3.7 The importance of physical activity as an outcome in young and middle-aged adults with hip-related pain.

Physical activity is a key modifiable factor globally for the prevention and management of many diseases. Evidence for the health benefits of physical activity and cardiovascular fitness is compelling, with cardiovascular fitness identified as a predictive factor in all-cause mortality[72, 134, 264]. The benefits of maintaining regular physical activity on wellbeing, health and longevity surpass the effectiveness of drugs or any other medical treatment[264]. This positive correlation is reflected in the development and implementation of global guidelines for physical activity[90, 102, 244]. Minimal guidelines for adults (aged 18 to 64) include 150 minutes of moderate-intensity physical activity or 75 minutes of vigorous-intensity physical activity per week[13, 265]. Positive benefits have been identified from maintaining leisure-time physical activity throughout the teenage to older-adult life span in reducing all-cause, cardiovascular disease-related and cancer-related mortality[211]. These factors further emphasise the need to effectively monitor physical activity as an outcome and minimise the possible negative impacts of hip-related pain and surgery.

The average hip arthroscopy patient is in their mid- to late-thirties[49, 150, 223] with high expectations the surgery will address deficits in physical activity[152]. Seeking improvements in general physical ability and sporting activity is a key motivator for patients undergoing hip arthroscopy[151]; however, there are indications this desire may remain unfulfilled post-surgery[152, 203, 231]. For many in this active population, their lifestyles will encompass multiple activities across the domains identified in Figure 2.4, including work, sport and family commitments. In addition to maintaining societal roles, being able to achieve desired levels of physical activity for this cohort is associated with perceived quality of life[64] and offers the potential to mitigate post-arthroscopy comorbidities, such as mental health disorders, chronic pain, cardiovascular disease and insomnia[203]. Monitoring physical activity expectations and outcomes is infrequently undertaken in studies of physiotherapist-led interventions for hip-related pain[127] and following surgical intervention for FAI syndrome[200]. Between two arms of a recent randomised controlled trial[184] a higher proportion of participants undergoing arthroscopy for FAI syndrome achieved their pre-operative expectations (31%) than those undertaking a physiotherapy programme (15%). These expectations related to the Hip Outcome score HOS activities of daily living subscale and no equivalent comparisons are currently available for physical activity and sport related outcomes.

In the context of this PhD thesis, physical activity is an important outcome from two major perspectives, these being:

- The importance of physical activity for general and hip-joint related health.
- The expectations relating to physical activity gains of young and middle-aged adults undergoing arthroscopic hip surgery.

2.3.8 Returning to physical activity after hip-arthroscopy.

Returning to physical activity following injury or surgery presents challenges from a physical and psychological perspective. When considering the sequelae of non-specific significant sport- or leisure-related injury, reductions in physical activity have been reported at 12 months following injury even where associated disability no longer persists[9], illustrating the potential complexity of the transition back to usual activity. These post-injury limitations were also associated with a substantial reduction in patients' meeting minimal activity recommendations, extending the issue beyond desired sports participation to physical activity for health. Similar concerns may apply to physical activity following hip arthroscopy. The reported average symptom duration of almost four years prior to surgery[214] and deficits in pre-operative activity are likely to further impact upon the desired transition to physical activity following hip arthroscopy.

The metabolic influence of body fat in facilitating the disease process of OA has been established[38, 255]. The average hip arthroscopy patient may be over-weight at the time of surgery[88, 223], potentially further increasing the morbidity of this group. The importance of physical activity for maintaining physical and mental wellbeing is unequivocal[22, 165] and could play an important role in moderating the incidence of potential comorbidities following hip arthroscopy, such as cardiovascular disorders, metabolic syndromes[203], mental health disorders[48, 203] and impacts on quality of life[64]. Utilising appropriate methods to identify and monitor physical activity in a manner acceptable to patients has the potential to facilitate individuals in achieving appropriate physical activity-related goals.

Much research pertaining to arthroscopic hip surgery focuses on athletic populations. Consequently, a successful return to physical activity is frequently described in terms of 'return to sport' or 'return to play'. Table 2.2 summarises the findings of seven recent systematic reviews that reported these return to sport or play criteria[5, 30, 147, 164, 166, 179, 201]. Dichotomous criteria for return to sport/play rely heavily upon the variable definitions of sport and what constitutes a 'successful return'. The inconsistency in these criteria may lead to overly optimistic claims of post-operative activity recovery[209, 267]. These claims can drive potentially unrealistic expectations for clinicians and patients. When more stringent, recommended definitions are applied[10], such as identifying the level of participation or performance achieved, estimations based on a dichotomous return to sport/play criteria may appear inflated[267]. For example, when return to optimal performance is considered as an additional criterion of success, this was achieved by fewer

than 20% of athletes returning to their pre-injury sport following hip arthroscopy for FAI syndrome[106]. For studies that do consider physical activity in a wider context than 'return to sport/play', using population-specific PROMs, there is evidence that physical activity remains compromised for post-hip arthroscopy cohorts at more than a year following surgery[64, 231]. Additionally, qualitative studies focusing on return to sport at more than one year after hip-arthroscopy have identified ongoing limitations[148, 235], with 43% of participants not returning to their pre-injury level of sport[235].

Table 2.2. Summary of return to sport data identified in systematic reviews.

Study	Number of studies included in review	Number of participants	Age (years) [range] or Mean±SD	Population – activity characteristic	Men:Women (%)	Mean Follow-up [range] or Mean±SD	Pooled return to sport prevalence[$]	Pooled return to sport prevalence at pre-injury or surgery level[$]
[†]Alradwan et al (2012)[5]	9 (2 non-arthroscopic)	418	25.4 [11 to 66]	Athletes	77:23	NR (Minimum 6 months)	92% (87 to 96)	88% (80 to 94)
[†]Casartelli et al (2015)[30]	18 (4 non-arthroscopic)	977	28 [15 to 41].	'Active in sport'- any level	76:24	2.3 years [0.5–5.0]	87% [range 56 to100]	82% [range 55 to 100].
[†]Lovett-Carter et al (2020)[147]	15	809	26 [11 to 66]	'Active in sport'- any level	80:20	26 months [3 to 97].	88.3% (83.4 to 92.4)	85.3% (77.6 to 91.6)
Memon et al (2019)[164]	38 (Total)	1773	27.6 [11 to 65]	Professional, competitive or recreational athletes	72:28	28.1 months [3–144]		
	26 (reporting return to sport)	1050					93% (87 to 97)	
	34 (reporting level of return)	1607						82% (74 to 88)
[†]Minkara et al (2019)[166]	31 (Total)	1911	29.9±1.9	No restrictions with respect to sport		29.5±13.9 months		
	10 (reporting return to sport)	554					87.7% (82.4 to 92.9)	
O Conner et al (2018)[179]	22 (Total)	1296	40.0±1.3	No restrictions with respect to sport	71:29	25.8±1.2 months		
	13 (reporting return to sport)					25.8±2.4 months	84.6% (80.4 to 88.8)	
[†]Reiman et al (2018)[201]	35 (reporting return to sport) (7 non-arthroscopic)	1634	27.1±7.8	Athletes	70:30		91% (88 to 94)	
	13 (reporting level of return)	570						74% (67 to 81)

[†]Only include studies reporting arthroscopy for femoroacetabular impingement syndrome; [$]Reported as 95% confidence interval unless otherwise stated; NR=not reported; SD=standard deviation.

While there are valid concerns that physical activity outcomes may be poorer post-arthroscopic hip surgery than previously implied in the literature, there is a deficit of evidence-based guidelines to support the post-operative return to desired physical activity[84, 195]. Consensus on safe return to sport recommendations following hip arthroscopy is lacking[53, 201] with clear criteria yet to be established[80]. Data from a scoping review of athlete-based studies identify an average return to sport time of seven months following surgery for FAI syndrome, although the reported mean range of 3 to 14.5 months illustrates the lack of consensus and observed variablility[201]. Early return to sport has been associated with possible increased risk of osteoarthritic change in a similar population profile of individuals undergoing knee surgery for anterior cruciate ligament reconstruction (ACLR)[46]. The protective association of evidence-based rehabilitation programmes, guiding return to physical activity, and long-term outcomes are well documented in relation to ACLR[83, 208]. The evidence to underpin such recommendations following hip arthroscopy is currently lacking.

Although hip arthroscopy can address a number of pathologies, it is most frequently undertaken for FAI syndrome with femoral osteoplasty being one of the most frequent procedures performed arthroscopically[49, 174, 212]. Different pathologies and interventions undertaken during hip arthroscopy have the potential to impact on an individual's return to physical activity. Despite the variations this may impose, distinctions made at a surgical level are less rigorously considered beyond the earliest stages of rehabilitation protocols. In the development of PROMs for young to middle-aged adults with hip-related pain, patient and clinician panels consider physical activity an important facet of recovery, irrespective of diagnosis or intervention[168, 230]. Returning to physical activity is a common goal across the range of arthroscopic procedures included in this thesis.

The barriers identified in successfully returning to sport and play for athletes following hip arthroscopy, such as fear of re-injury, the desire to prevent further damage and the continuation of hip-related symptoms[52, 76, 186, 213], are equally likely to apply to any patient returning to physical activity post-operatively. Achieving a successful return to physical activity requires the desired physical goals to be identified and approached sequentially through a graded rehabilitation programme. However, both physical and psychological readiness are required for a successful return to sport[190]. Such psychological influences will play a role at all levels of physical activity, applying to different dimensions and domains. Developing valid, user-friendly tools to monitor progress and enable the identification of 'at risk' individuals is vital in advancing care to enable a smooth transition back to physical activity after hip-arthroscopy. Tools currently exist to assess psychological readiness for returning to sport following ACLR; however, no tools are currently validated to guide clinical decision-making following hip arthroscopy.

Return to sport/play has received attention for the athletic population, but the broader consideration of physical activity presents greater challenges to capture effectively. While known deficits exist between subjective and objective assessment of physical activity in other areas, objective activity for this patient group has yet to be explored. A novel approach to this, using commercial activity devices (accelerometers), requires underpinning investigation of device validity and reliability for this cohort. Identifying patients' beliefs and expectations is fundamental to developing a clear picture of post-arthroscopy activity engagement, an area unexplored for a broad range of activity engagement at six months post-arthroscopy. The influence of psychological readiness on a successful return to activity is embedded in the field of ACLR research; however, a means of assessing this for post-hip arthroscopy patients has yet to be established.

2.4 Synopsis of current gaps in evidence and understanding

Hip-related pain can negatively impact upon engagement in a broad spectrum of physical activity, with sports-specific deficits identified prior to hip-arthroscopy and perceived physical activity impairments identified using PROMs. Such restrictions can be a common driving force of seeking surgical solutions to hip-related pain (Figure 2.10). Despite high expectations of young and middle-aged adults to return to physical activity following hip arthroscopy, our understanding of post-operative physical activity is limited. As no clearly established guidelines currently exist to guide a safe and effective return to physical activity following hip-arthroscopy, it is necessary for research findings to underpin the evolution of consistent information for patients and clinicians.

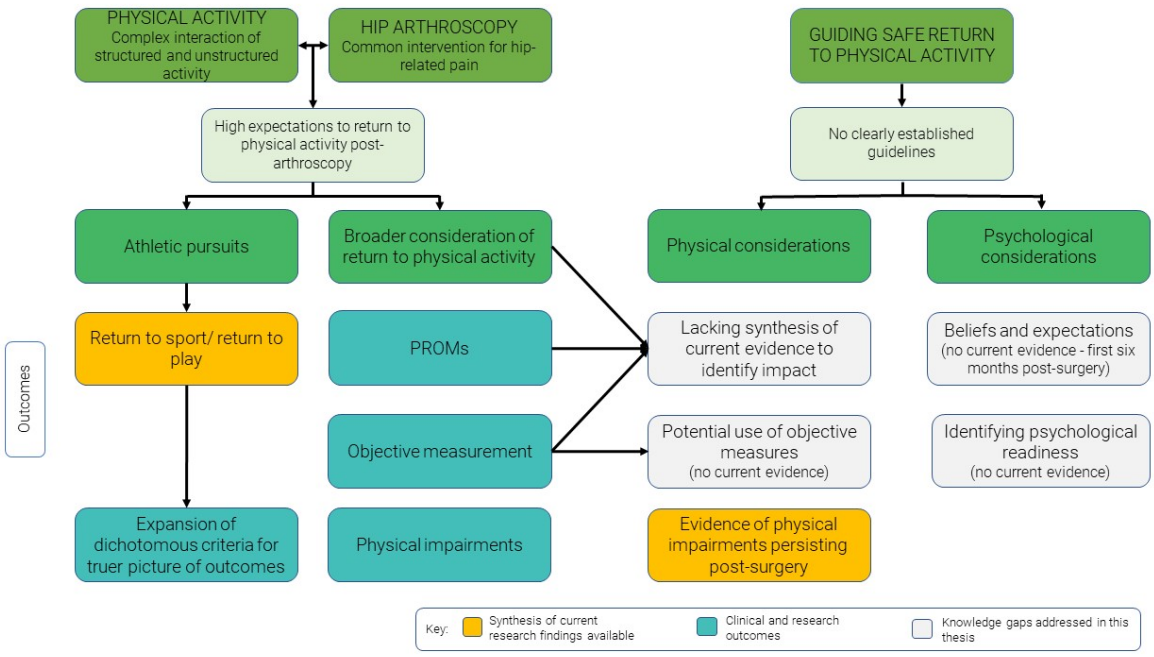

Figure 2.10. Overview of physical activity following hip arthroscopy.

To date, research has focused primarily on athletes and their return to competitive sport following arthroscopic hip surgery. For individuals with an affiliation to specific sporting activities, return to sport/play has most frequently been recorded as a dichotomous outcome (i.e., return to sport/play: yes/no). Recognition of the limitations of this outcome is evolving, with recent publications implementing the recommendation to capture more comprehensive outcome data, including measures of the type of sport, level and performance. A picture of physical activity as a broader concept, encompassing less-structured recreational activity and activity across different domains, can be captured using PROMs, objective measurement and assessment of persisting physical impairments which may also influence return to physical activity; however, understanding of this broader sphere of physical activity is less well established.

It is known that deficits, such as reduced muscle strength, persist post-arthroscopy[85, 121] and that success in returning to physical activity is reported variably in the literature. No synthesis of evidence currently exists focusing on a return to physical activity, rather than the return to sport. A systematic review (Study 1 in this thesis) has the potential to enhance understanding of the impact of surgery on the broader concept of physical activity and to identify the current utilisation of subjective and objective outcome measures for research purposes.

Objective and subjective reports of physical activity differ in nature. PROMs have been favoured in the literature to date. A clear profile of objectively measured physical activity after hip arthroscopy is yet to be established. Commercial activity trackers (accelerometers) are popular and offer a potential means to objectively measure physical activity, although the reliability and validity of commercial devices to objectively assess physical activity in this cohort is unknown.

Understanding of physical and psychological perspectives are essential in guiding a safe return to physical activity after surgery. Insights into patient-perceived barriers to, and the impact of, returning to physical activity after hip arthroscopy are limited. To date, in-depth appraisals of patient insights have not been sought during the first six months post-hip arthroscopy. Additionally, the psychological readiness of individuals to return to physical activity following hip-arthroscopy is poorly understood. A valid and reliable method of assessment has yet to be established for young to middle-aged patients following hip-arthroscopy.

2.5 Summary

Physical activity is a modifiable factor that may have positive and negative implications for young to middle-aged adults with hip pain preceding or following hip arthroscopy. Attaining physical activity goals is important for both personal reasons of health and wellbeing and to fulfil societal roles. To date,

research has focused primarily on athletes and their return to competitive sport following arthroscopic hip surgery. Despite the importance of this outcome, our understanding of post-operative physical activity is equivocal. Little is known about the quantity and quality of physical activity undertaken and the factors that may influence a successful transition to physical activity participation following surgery. Expanding the knowledge base surrounding physical activity following hip-arthroscopy, and its measurement, is a key factor in optimising recovery after this relatively common procedure.

An infographic representation of the questions related to this thesis is presented in Figure 2.11.

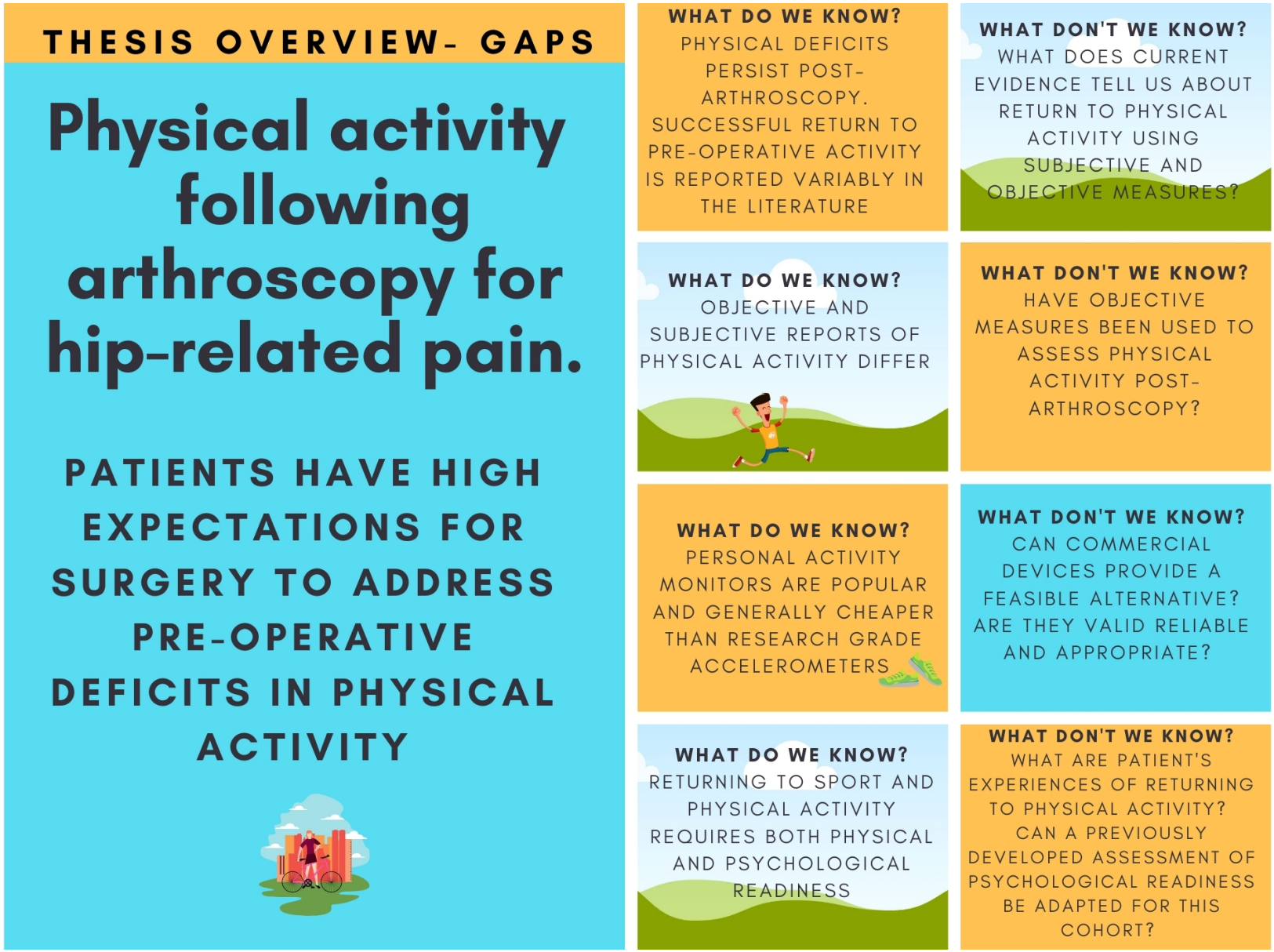

Figure 2.11. An overview of evidence gaps and research questions.

CHAPTER 3 (STUDY 1): PHYSICAL ACTIVITY FOLLOWING HIP ARTHROSCOPY IN YOUNG AND MIDDLE-AGED ADULTS: A SYSTEMATIC REVIEW

Chapter 2 identified the importance of regaining optimal physical activity for young and middle-aged adults undergoing hip arthroscopy and the scope of outcome measures that might be used to capture these diverse data. Return to physical activity is reported variably in the literature and a synthesis of current evidence is lacking. This systematic review was undertaken to evaluate the impact of hip arthroscopy on physical activity and consider the range of outcome measures utilised in research, particularly the use of emerging technologies, such as activity trackers.

This chapter contains the following publication in its entirety:

Jones, D. M., Crossley, K. M., Ackerman, I. N., Hart, H. F., Dundules, K. L., O'Brien, M. J., . . . Kemp, J. L. (2020). Physical activity following hip arthroscopy in young and middle-aged adults: A systematic review. *Sports Medicine-Open, 6*(7). https://doi.org/10.1186/s40798-020-0234-8

Additional files are included in Appendix 2

Sports Medicine - Open

SYSTEMATIC REVIEW Open Access

Physical Activity Following Hip Arthroscopy in Young and Middle-Aged Adults: A Systematic Review

Denise M. Jones[1*], Kay M. Crossley[1], Ilana N. Ackerman[2], Harvi F. Hart[1,3], Karen L. Dundules[1], Michael J. O'Brien[1], Benjamin F. Mentiplay[1], Joshua J. Heerey[1] and Joanne L. Kemp[1]

Abstract

Background: Hip arthroscopy is a common surgical intervention for young and middle-aged adults with hip-related pain and dysfunction, who have high expectations for returning to physical activity following surgery. The purpose of this review was to evaluate the impact of hip arthroscopy on physical activity post-arthroscopy.

Methods: A systematic search of electronic databases was undertaken in identifying studies from January 1st 1990 to December 5th 2019. The search included English language articles reporting physical activity as an outcome following hip arthroscopy in adults aged 18-50 years. Quality assessment, data extraction and synthesis of included studies were undertaken.

Results: Full text articles (n = 234) were assessed for eligibility following screening of titles and abstracts (n = 2086), yielding 120 studies for inclusion. The majority (86%) of the studies were level 4 evidence. One study reported objective activity data. The most frequently occurring patient-reported outcome measure was the Hip Outcome Score-sport-specific subscale (HOS-SS, 84% of studies). Post--arthroscopy improvement was indicated by large effect sizes for patient-reported outcome measures (standard paired difference [95% confidence interval] −1.35[−1.61 to −1.09] at more than 2 years post-arthroscopy); however, the majority of outcome scores for the HOS-SS did not meet the defined level for a patient-acceptable symptom state.

Conclusion: The current level of available information regarding physical activity for post arthroscopy patients is limited in scope. Outcomes have focused on patients' perceived difficulties with sport-related activities with a paucity of information on the type, quality and quantity of activity undertaken.

Level of Evidence: Level IV, systematic review of Level 2 through to Level 4 studies

Keywords: Outcomes, Hip-arthroscopy, Activity, Sport, Rehabilitation

Key Points

- The systematic collection of a range of physical activity outcomes is required in both clinical and research settings to effectively monitor and support post-arthroscopy recovery, building a more comprehensive activity profile of patients that moves beyond athletic classification.
- Physical activity outcomes are important but diverse and poorly captured in the current literature. The appropriateness of the patient-reported outcomes most commonly employed to measure physical activity is questionable and the range limited.
- The majority of patients feel better in relation to their ability to undertake physically active tasks including sports, but fail to progress to 'feeling good' or a patient-acceptable symptom state.

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Background

Hip arthroscopy is an increasingly common surgical intervention for young and middle-aged adults with hip-

related pain or dysfunction [1–4]. Indications for hip arthroscopy most frequently include persistent pain and altered bony morphology associated with femoroacetabular impingement syndrome (FAIS) in addition to labral tears, chondral defects and ligamentum teres injuries [5, 6]. Young and middle-aged adults undergoing hip arthroscopy have high expectations for returning to physical activity to support their social and cultural roles [7]. Despite this expectation, physical activity-related outcomes are only reported in approximately a quarter of studies investigating surgical intervention for FAIS [8], returning to sport or play being the predominant outcome assessed. A high level of return to sport/ return to play following hip arthroscopy (88–91%) has been reported in a number of systematic reviews [9–16] ; however, recent study findings suggest the need for a more expansive analysis, beyond these simplified nominal criteria, to assess the wider impact of hip arthroscopy on physical activity. When adding the further consideration of level to sports status, Ishøi et al. [17] identified a relatively low return to pre-injury sport at pre-injury level of 57%, and Thorborg et al. [18] identified that at 1 year post-arthroscopy, only 25% of patients that met physical activity reference scores commensurate with those expected in a healthy population.

Dichotomous return-to-sport or return-to-play outcomes only provide a narrow perspective of physical activity which comprises multiple constructs such as the type, quantity, intensity and quality of activity, as well as physical activity-related impairments such as pain or discomfort. As these multiple dimensions imply, capturing comprehensive physical activity data is challenging and unlikely to be attained using a single measure [19]. One potential method of capturing data is through the use of patient-reported outcome measures (PROMs). Recommended PROMs with adequate clinometric properties for patients following hip arthroscopy include the Copenhagen Hip and Groin Outcome Score (HAGOS), International Hip Outcome Tool (iHOT-33) and Hip Outcome Score (HOS) [20–22]. While subscales of these PROMs primarily provide information on the degree of difficulty that patients experience with sport-related activities, other PROMs such as the Hip Sport Activity Scale (HSAS) provide information on the level of activity undertaken [23]. In addition to questionnaires, with advancing technology, potential exists to gather objective information relating to physical activity. Duration and intensity of physical activity may be captured through the use of motion sensors, accelerometry and mobile phone applications. Although an overview from ClinicalTrials.gov [24] lists over 1500 trials using accelerometry as an outcome measure, only 118 of these are related to musculoskeletal problems and less than 5 are related to the hip. The extent to which these newer technologies are being used and reported in relation to the outcomes following hip arthroscopic surgery has yet to be described.

To gain a comprehensive understanding of the impact of hip arthroscopy on the physical activity of patients, it is necessary to consider a range of outcomes and include both competitive and non-competitive (recreational) physical activity. Within the context of this review, physical activity is deemed to be an activity exceeding that which is required for normal activities of daily living, interpreting sport in a wider community context [25]. While arthroscopic interventions continue to evolve and increase in popularity [2, 4, 26], our current understanding of post-arthroscopy outcomes, in terms of physical activity, remains limited.

Review Aim:

The primary aim of this systematic review is to examine quantitative primary research, reporting level IV evidence or above, to assess the impact of hip arthroscopy, undertaken for hip-related pain and dysfunction, on the physical activity of young and middle-aged adults. This will be assessed via the study outcomes presented. In addition, an overview of the outcomes used will be described.

Methods

Protocol and Registration

The protocol for this review was registered with the International Prospective Register of Systematic Reviews (PROSPERO, registration no. CRD42017080527). Amendments were made to the original protocol to (i) clarify exclusion criteria and (ii) modify outcomes in light of literature published during completion of the current review.

Eligibility Criteria for Inclusion in the Review

Pre-specified inclusion and exclusion criteria are identified in Table 1.

Literature Search Strategy and Study Selection

A comprehensive search strategy was developed for the following databases: Scopus, MEDLINE, CINAHL, PubMed, AUSPORT, SPORTDiscus, PEDro and PsycINFO. The search was restricted to articles from January 1st 1990, due to the limited literature on hip arthroscopic surgery prior to this date, through to January 16th 2018. The search was updated through to December 5th 2019.

The search was conducted independently by two reviewers (DMJ, JJH), with the strategy adapted as appropriate for the requirements of each database. An example of the full search strategy is given in Additional file 1. Citation tracking of key articles was undertaken using Web of Science and Google Scholar. A manual check of reference lists of key articles was also undertaken. References were imported into Endnote X6

Table 1 Inclusion and exclusion criteria

	Inclusion	Exclusion
Participants	18–50 years (Average age to fall in this range)	▪ Evidence of OA (> 10% of cohort with Tönnis grade 2 and above or joint space width of > 2 mm)
		▪ Dysplasia (LCEA mean for cohort < 20° &/or > 10% of the group with LCEA < 20°)
Intervention	Primary hip arthroscopy	▪ Secondary hip arthroscopy
		▪ Arthroscopy following hip joint arthroplasty
		▪ Studies in which arthroscopic and open procedures are combined
		▪ Studies in which primary focus is non-articular surgery
		▪ Studies in which periarticular osteotomy forms part of the procedure
Study types	Level IV evidence or above (RCT; prospective and retrospective observational studies)	▪ Case series < 5 participants
		▪ Published abstracts and non-peer-reviewed studies
		▪ Non-English language papers
Outcomes	Report change in physical activity and/or volume of sport participation	▪ Papers solely reporting prevalence of return to sport/return to play and/or sport-specific measures such as number of goals scored/career length
		▪ Return to work (including military service)
		▪ PROMs in which physical activity-related outcomes do not exceed normal activities of daily living

OA osteoarthritis, *LCEA* lateral centre edge angle, *PROM* patient-reported outcome measure, *RCT* randomised controlled trial

(Thomson Reuters, Carlsbad, California, USA) and duplicates removed. Title, abstract and full text screen were undertaken by two teams of independent reviewers (DMJ, JJH, BFM). Any disagreements were resolved by a fourth independent reviewer (JLK).

Study appraisal

All included papers were assessed using an adaptation of the assessment form for observational studies created by Siegfried et al. [27], utilising further examples from Ganderton et al. [28, 29]. Copies of the appraisal form are given in Additional file 2. The tool considers biases relevant to observational studies in general and those specific to the research question. To address the research-specific biases, four authors (DMJ, JLK, KMC, JJH) compiled a list of potential confounding factors such as age, sex and the degree of degenerative change in the hip joint. As the majority of studies were non-randomised controlled trials, this approach was undertaken to align with good practice guidelines outlined by the non-randomised studies methods group of the Cochrane Collaboration [30]. This tool was used to assess methodological quality of all included studies by two teams of reviewers (DMJ, KD, MO, BM). Disagreements were resolved through discussion and, where necessary, consensus agreed with an independent arbitrator (JLK). Agreement between raters was determined using percentage-observed agreement and Cohen's Kappa (κ). Itemisation and display of each aspect was presented in its raw form for each study. An assessment of level of evidence was made against the Oxford Centre for Evidence-Based Medicine criteria [31]

Data extraction, synthesis and analyses

Data for each included study were extracted independently by two teams of reviewers (DJ, KD, MO, BM) using a standardised form adapted from the Cochrane Effective Practice and Organisation of Care (EPOC) criteria [32]. Inconsistencies were resolved by consensus discussion with arbitration from a third reviewer (JLK) if needed. Study authors were approached by email with requests for further data if required.

Data regarding study design, participant demographics (age, sex, physical activity attributes), outcome measures, duration of follow-up, arthroscopic findings and intervention were extracted and collated. The primary indication for surgery was noted (if specified). Where sufficient data were available, sports activities were categorised using previously established criteria in which activities are grouped based on the mechanical load placed on the hip joint (Table 2) [33, 34].

To accommodate heterogeneity in the reporting of duration of follow-up, data collection points were collated under the following time frames: ≤ 6 months, 7–12 months, 13–18 months, 19–24 months, ≥ 25 months. Improvements in activity-specific subscales are known to be limited beyond 2 years post-arthroscopy [11, 35].

Reported outcomes were assessed to identify the direction and consistency of effect, and where appropriate data were available, standard paired differences (SPD) were calculated to present a magnitude of effect between

Table 2 Categories of sports activities, based on hip joint load

Category	Included activities
Cutting	Soccer, basketball, lacrosse, field hockey, downhill skiing, snowboarding
Flexibility	Dancing, gymnastics, yoga, cheerleading, figure skating, synchronized swimming, martial arts, rock climbing
Contact	Football, rugby, wrestling
Impingement	Ice hockey, crew/rowing, baseball catching, water polo, equestrian polo, breaststroke swimming, weight lifting, bobsled, crossfit, horseback riding
Asymmetric/ overhead	Baseball, softball, tennis, golf, volleyball, athletic field events, fencing, badminton, cricket, squash, racquetball, handball
Endurance	Track, cross-country, other running, cycling, swimming (not breaststroke), cross-country skiing, biathlon, aerobics

time points. This was determined by the within-group difference between time points, divided by the pre-score standard deviation (SD). Where standard errors (SE) were reported, SD was calculated (SD = SE*√number of participants). The magnitude of SPDs was interpreted as large effect (≥ 0.8), moderate effect (0.5–0.79) and weak effect (0.2–0.49) [36]. The 95% confidence intervals for SPDs were calculated. Where appropriate summary scores were available for whole cohorts in studies with more than one arm, these data were used in preference to group data. Where data were insufficient for SPDs to be calculated, relevant study conclusions were reported where available.

To provide a visual representation of HOS-SS outcome scores, all data points from study groups were plotted against the minimal clinically important difference (MCID) and patient-acceptable symptom state (PASS) for this subscale (a change of 6 points and score of 75 points, respectively [21, 37, 38]). These scores were interpreted as 'feeling better' (MCID) and 'feeling good' (PASS) [39].

Pooling of data was undertaken where outcomes were statistically and clinically homogeneous. Any studies with potential replication of participants were excluded from this analysis. Where no responses were offered from authors to enable discrete cohorts to be identified, the study encompassing the widest time frame with the greatest number of participants was chosen from studies generated within the same research setting, utilising the same outcome measures and database. Where more than one outcome was reported in a study, the most frequently occurring outcome score across all studies was chosen to be reported in pooled data. Studies reporting number of participants or number of hips were included in the pooled data. Where reporting was unclear, a conservative approach was taken with calculations being made in relation to the lowest number of potential participants. Pooled data were examined using forest plots (Review Manager (RevMan) [Computer program]. Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). Duration of follow-up categories were further merged to provide pooled data for the following time frames: 6 to 12 months, 13 to 24 months and ≥ 25 months. Studies were only reported once in each time frame.

Results

Search Strategy

The number of records considered at each stage of the review and the reason for exclusions are shown in Fig. 1. In total, 120 studies were included in the review. A list of excluded studies is provided in Additional file 3.

Study Characteristics

The included studies [6, 17, 18, 35, 37, 40–154] comprised two randomised controlled trials (RCTs), 24 prospective studies and 94 retrospective studies, of which 41 were single-arm case series (Additional file 4: Characteristics and outcomes of included studies). Author requests were made in relation to 51 (43%) studies to attain unreported data and query potential replication of participant data between studies. Additional information was supplied for five studies [18, 89, 99, 100, 112].

One hundred and twelve (93%) studies were conducted on a single site and/or involved the patients of one surgeon (Table 3). One hundred studies (83%) were from North America, 12 from Europe (10%) and 3 from Australia (2.5%). Three studies were from Korea, 1 from China and 1 from Israel.

A mix of reporting approaches was used, the majority of studies providing data based on participants (20,154 participants), the remainder recording 1,446 hips/procedures. We were unable to exclude the possibility of participants appearing in more than one study due to the high number of studies retrospectively reviewing databases. The number of participants in studies ranged from 11 to 1835. The mean (± SD) age of participants was 34 ± 7 years with 58% of the data pertaining to women. Seventy-two percent of studies specified FAI/FAIS as the primary inclusion pathology.

One study [154] reported objective measures of physical activity utilising accelerometry. The majority (n = 99, 83%) presented the Hip Outcome Score-sport-specific subscale (HOS-SS, Fig. 2). The 'Function in Sport and Recreation subscale', subscale of the Hip disability and Osteoarthritis Outcome score (HOOS-SS) and the two relevant subscales ('Physical Function in Sport and Recreation', 'Participation in Physical Activities') of the Copenhagen Hip and Groin Outcome Scores (HAGOS-SR; HAGOS-PA) were presented in 8 (7%) and 8 (7%) of studies, respectively. An overview of

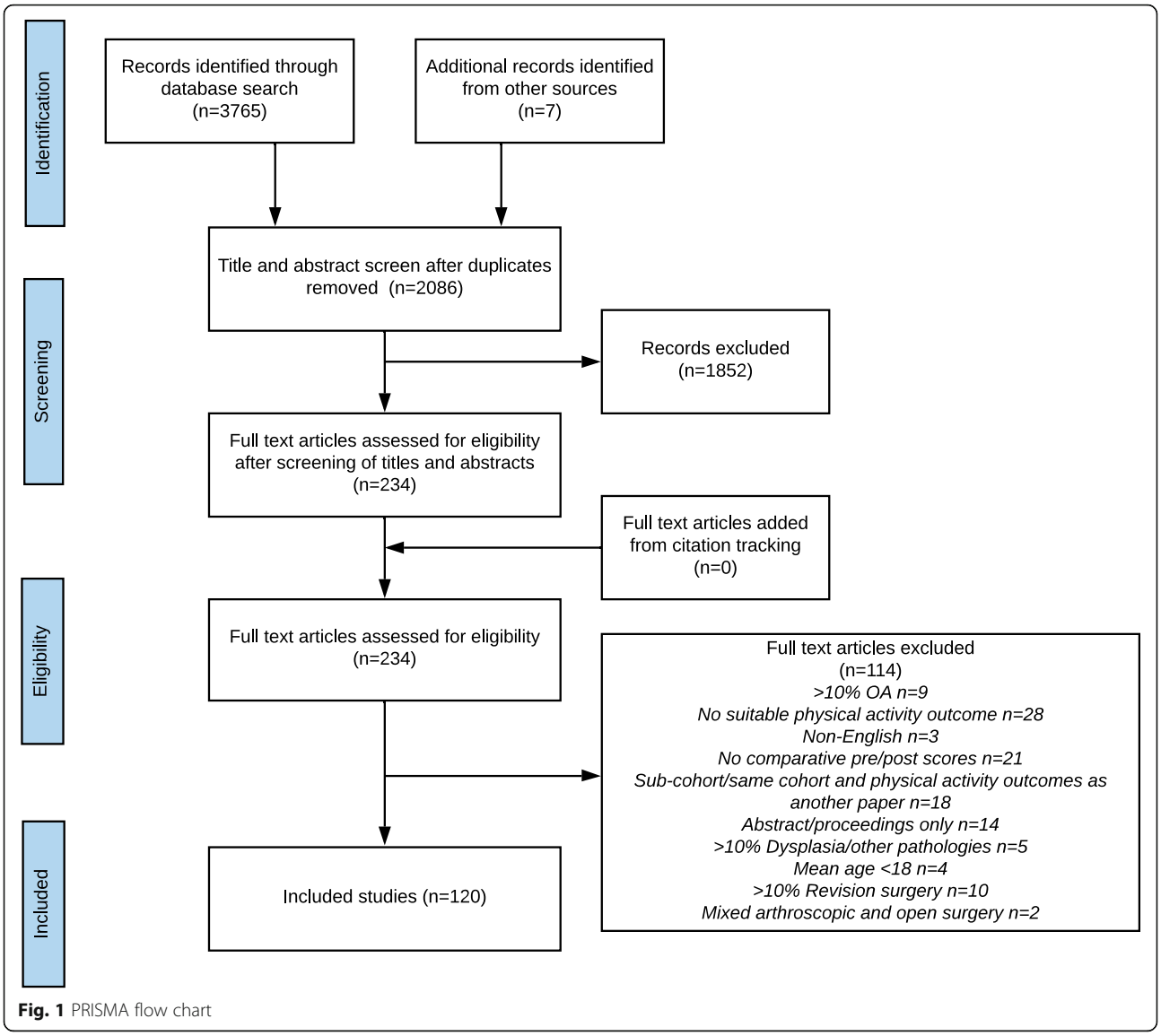

Fig. 1 PRISMA flow chart

PROMs is included in Additional file 5. The 'Sports and Recreational Activities' subscale of the International Hip Outcome Tool (iHOT-33 SR), Tegner Activity Scale (Tegner) and Hip Sports Activity Scale (HSAS) were reported in 2 (2%) of studies, while the UCLA Activity Score and Functional Activity Score (FAA) were each reported in a single study (Additional file 4). Outcome scores for studies with multiple time points of data collection can be found in Additional file 6. All but two studies reported pre- and post-arthroscopy results. Kemp et al. [89] provided an assessment of two post-arthroscopy time points; Tijssen et al. [124] reviewed changes from pre-injury to post-arthroscopy.

Thirty four (28%) of the reviewed studies included some assessment of physical activity attributes of the cohort such as type of activity (e.g. 'recreational', 'professional'; work activity or Tegner Activity Scale) with a similar proportion providing sufficient data to enable categorisation of activity type (as identified in Table 2; n = 30, 25%). A summary of inclusion/exclusion criteria for each study, arthroscopic intervention and findings are given in Additional file 7.

Quality assessment scores

Observed agreement between quality assessors was 99.6% (1554 out of 1560 items), where κ = 0.53, representing moderate inter-rater agreement [155].

All studies employed PROMs; however, the reporting of validity and reliability of these outcomes was deemed adequate in only 26 (22%) of the studies. Complete quality assessment scores are provided in Additional file 8 and a summary is provided in Table 3. Blinding of those assessing data was poorly addressed in all but six studies (5%) and only six studies (5%) provided clearly

Table 3 Summary of study quality assessment

			Internal Validity													
	External Validity		Performance	Detection				Attrition	Selection bias/control of confounding							
Study	Representative ✓	[1]Participation rate ✓	Direct observation ✓	PROM-validity/ reliability ✓	[2]Direct measure - validity/ reliability	Blinded assessors ✓	[3]Outcome measure ✓	[1]Completeness ✓	[4]Age ✓	Location ✓	[5]Sex ✓	[6]Severity of Joint disease ✓	[7]Follow-up ✓	Single site &/or surgeon(YES)	LOE
RCTs															
n=2	2	2	2	2	NA	2	2	0	1	2	0	2	1	1	2
Prospective studies, more than 1 arm															
n=13	10	13	13	9	1	1	13	11	3	12	8	10	1	12	3
Prospective studies, Single-arm															
n=11	5	6	10	7	NA	1	11	8	2	11	3	7	1	9	3/4
Retrospective studies, more than1 arm															
n=53	41	48	53	2	NA	1	49	43	3	52	37	44	2	51	4
Retrospective studies, Single-arm															
n=41	32	40	40	6	NA	1	40	35	3	40	7	35	0	38	4

RCTs randomised controlled trials, *LOE* level of evidence (Oxford Centre for Evidence-Based Medicine [31]), *PROM* patient-reported outcome measure.
✓ indicates the measure was adequately addressed in the study
[1]✓ percent participation/ completion was 80% or more.
[2]NA indicates no direct measure of PA used
[3]✓ indicates same method of ascertainment was used for all participants
[4]✓ if range within 18–50
[5]✓ if sex is balanced (10% or less difference) or adjusted for in analysis
[6]✓ if severity of OA identified in the study
[7]✓ where FU is the same for all study participants or lies within 10%, i.e. the following acceptable ranges: 1 year follow-up = 1 month each way; 2 years follow-up = 2 months; 3 years follow-up = 3 months……10 years = 10 months
LOE=Level of evidence (Oxford Centre for Evidence-Based Medicine [31]); PROM=patient-reported outcome measure

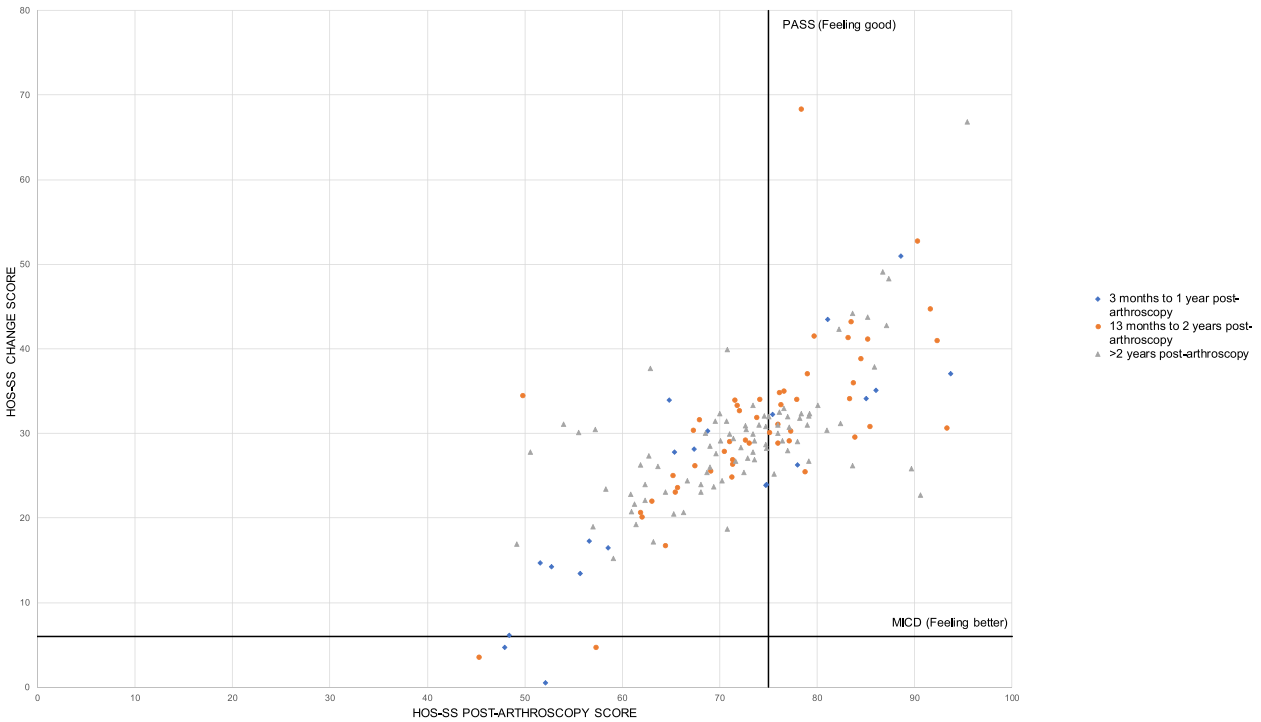

Fig. 2 Hip Outcome Score-Sport Scale (HOS-SS) outcome scores for study groups at all time points. Points above the MCID (minimal clinically important difference) line represent a sufficient change in HOS-SS score pre- to post-arthroscopy to identify 'feeling better'. Points to the right of the PASS (patient acceptable symptom state) represent a sufficiently high HOS-SS score at follow-up to identify 'feeling better'

identifiable time points in which all follow-up outcomes related to analogous time frames. Although the mean age of participants in all studies met the current inclusion criteria, 108 studies (90%) included some participants outside this age range or failed to report sufficient information.

Main Findings

Large effect sizes for patient-reported physical activity (where able to be calculated) were seen in all studies at latest follow-up for the HOS, HOOS, HAGOS and iHOT33 subscales, with the exception of ten study groups for the HOS [44, 80, 85, 97, 98, 138, 142, 144, 146, 147]; and one for HAGOS [17] in which effect sizes were moderate pre- to post-arthroscopy. In assessing progress between two post-arthroscopy time points, Kemp et al [89] determined a small effect size for the HOOS-SR. The direction of change was consistently toward improvement across studies. Table 4 shows the summary of the range (minimum SPD and maximum SPD) of effect sizes for each score across all studies for individual outcomes. The full set of results of SPDs are contained in Additional file 4.

Pre- to post-arthroscopy change in the HSAS was assessed in four studies [6, 99, 118, 131]. No effect and small effect were evident at 6 months post-arthroscopy in the RCT conducted by Bennell et al. [131] compared to a moderate effect size at 6 months post-arthroscopy reported by Sansone et al. [118] (SPD [95% CI]; 0 [−0.79 to 0.79]; 0.12 [−0.89 to 0.65]; −0.63 [−0.94 to 0.33] respectively). Two studies [6, 99] showed small effect sizes at approximately 2 years (SPD [95% CI]; −0.33 [−0.49 to 0.16]; −0.41 [−0.48 to 0.34]). Bennell et al. [131] was the only study to assess pre- and post-arthroscopy Tegner scores, finding large-to-moderate effect sizes at 6 months post-arthroscopy (SPD [95% CI]; −0.90 [−1.74 to 0.07]; −0.64 [−1.43 to 0.15]).

A visual representation of all HOS-SS outcome scores is presented in Fig. 2. Two studies [49, 100] had outcome scores sitting below the MCID and PASS scores (3% of all included data points). Sixty percent of outcome data points failed to reach the magnitude required to reach the PASS score. For data points relating to a follow-up duration of ≥ 25 months, 64% failed to reach the PASS score.

Data were pooled for HOS-SS, HOOS-SR, HAGOS SR and iHOT-33 SR and grouped according to time frame (Fig. 3). A large effect was evident for SPDs at each time frame (SPD [95% CI]; −1.22 [-1.41 to −1.03]; −1.06 [−1.24 to −0.88] and −1.35 [−1.61 to −1.09] at 6–12 months, 13–24 months and ≥ 25 months, respectively). Considerable heterogeneity was evident between studies in all time frames (I^2 79% to 92%).

Eight studies [73–75, 95, 116, 124, 126, 154] reported quantified changes in physical activity. Methods used in

Table 4 Range of effect sizes for each instrument across all studies (pre- to post-arthroscopy)

Measure	Study	Number (*n*)	Follow-up period	*SPD (95% CI)
HOS-SS	Wu et al .[128]	68	≥ 25 months	− 5.27 (− 5.98 to − 4.55)
	Rhee et al. [115]	37	7-12 months	-0.52 [-0.98 to -0.05]
HOOS-SR	Flores et al. [70]	39	7 to 12 months	-2.02[-2.57 to -1.47]
	Ibrahim et al. [85]	88	≥25 months	-0.63[-0.93 to -0.32]
HAGOS-SR	Bennell et al.[Group 1] [131]	11	≤6 months≥	-2.21 [-3.24 to -1.17]
	Ishoi et al. [17]	108	25 months	-0.66 [-0.93 to -0.38]
HAGOS-PA	Sansone et al. [118]	85	7 to 12 months	-1.48 [-1.82 to -1.14]
	Lund et al. [99]	1835	21 to 42 months	-0.85 [-0.92 to -0.78]
HSAS	Lund et al. [99]	1835	21 to 42 months	-0.41 [-0.48 to -0.34]
	Bennell et al. [131]	11	≤6 months	0 [-0.79 to 0.79]
Tegner	Bennell et al. [Group 1] [131]	11	≤6 months	-0.9 [-1.74 to -0.07]
	Bennell et al. [Group 2] [131]	11	≤6 months	-0.64 [-1.43 to 0.15]

n number of participants, *SPD* standard paired difference, *CI* confidence interval, *HOS-SS* Hip Outcome Score-Sport Scale, *HOOS-SR* Hip Disability and Osteoarthritis Outcome Score-Function in Sport and Recreation, *HAGOS-SR/PA* The Copenhagen Hip and Groin Outcome Score-Physical Function in Sport and Recreation / Participation in Physical Activities, *HSAS* Hip Sports Activity Scale, *Tegner* Tegner Activity Scale,
*Interpreted as large effect (≥ 0.8), moderate effect (0.5–0.79), and weak effect (0.2–0.49) [36]

these studies were largely sport-specific, e.g. change in swimming distances pre- to post-arthroscopy [74] or number of holes of golf played per week [126]. Decreases were evident in all measures, although this change was not significantly different in five of the studies [73–75, 116, 126]. Significant decreases were reported in running mileage [95] ($P < 0.001$) and sport frequency [124] pre-injury to post-arthroscopy. Kierkegaard et al [154] identify a self-reported four-fold increase in hours of physical activity per week but no significant differences were reported for accelerometry-derived activity data such as the percentage of time spent in undertaking moderate or high physical activity, step count or percentage of time running between pre-arthroscopy and 1-year post-arthroscopy (Additional file 4).

Discussion

This systematic review evaluated the impact of hip arthroscopy, undertaken for hip-related pain and dysfunction, on the physical activity of young and middle-aged adults. A limited range of relevant outcomes were reported, with PROMs, specifically the HOS-SS predominating, and one study using objective measures to monitor physical activity. Consistency was seen across PROMs for improvements post-arthroscopy; however, the majority of HOS-SS scores did not reflect a patient-acceptable symptom state. In interpreting the evidence, it should be noted that considerable heterogeneity was evident between study designs and eligibility criteria. The majority of studies (78%) were retrospective, the preponderance of level 4 evidence, thus having the potential to inflate positive outcomes and effect sizes.

Pooled data showed large effect sizes for the PROM subscales included in the analysis (HOS-SS, HAGOS-SR, iHOT-33 SR), depicting improvements in patients' perceived difficulties with sport-related activities. This was consistent within each time frame for data covering 6 to ≥ 25 months post-arthroscopy. Across all pooled data, four studies demonstrated extreme positive effects. Three of these studies [54, 101, 120] involved participants undertaking high-level physical activity with elevated post-arthroscopy scores. Conversely, Michal et al. [102] reported very low pre-arthroscopy scores in a cohort who underwent surgery for subspinal decompression. Excluding these studies from the analysis did not impact on the large pooled effect sizes. While the pooled data reflect a positive trend of patient-reported improvements in relation to physical activity impairments, isolated analysis of the HOS-SS raised questions about whether the magnitude of improvement was sufficient to be perceived by patients as satisfactory recovery of physical activity. The failure of 64% of reported HOS-SS scores to meet the PASS level for this scale beyond 2 years post-arthroscopy, echoes previously identified deficits in the HAGOS-SR and HAGOS-PA scores for patients at 1 year post-arthroscopy compared to their healthy peers [18]. These findings should encourage clinicians to monitor and support patients' return to physical activity for extended time spans following hip arthroscopy. The heterogeneity of the study cohorts, in relation to number of participants, age range, diagnosis, surgical procedures, physical activity background and time point at which data were gathered, potentially underlies the spread of outcomes depicted in Fig. 2, although this speculation also requires further investigation into the suitability of the outcome measure for the population.

Our findings indicate the need for more in-depth analysis of the impact of surgery on sport and activity involvement at an individual level. The limited range of outcomes utilised within studies was insufficient to answer questions about how much activity patients are

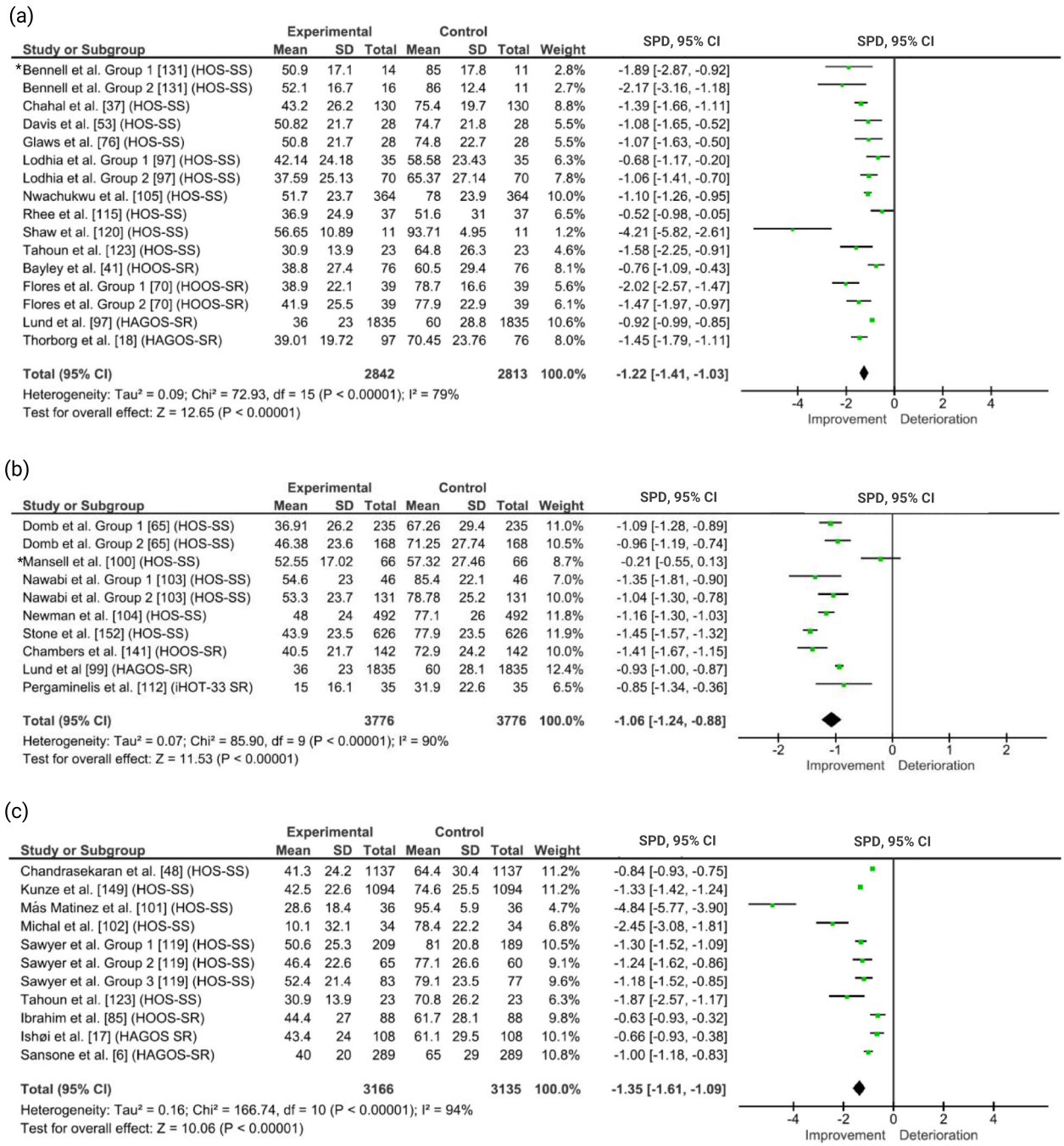

Fig. 3 Pooled effect sizes of pre- to post-arthroscopy including Hip Outcome Score-Sport Scale (HOS-SS), Hip disability and Osteoarthritis Outcome Score-Function in Sport and Recreation (HOOS-SR), The Copenhagen Hip and Groin Outcome Score-Physical Function in Sport and Recreation (HAGOS-SR) and International Hip Outcome Tool-Sports and Recreational activities (iHOT-33 SR) at 6–12 months (**a**); 13–24 months post-arthroscopy (**b**) and ≥ 25 months (**c**), showing standard paired difference (SPD) and 95% confidence intervals (CI). Weightings relate to study size. Randomised controlled trials are indicated with *

undertaking and at what level of involvement. Despite the rising interest in and accessibility of wearable technology in health and fitness [156], and the increasing use of activity monitors within health research [24, 157], we found only one study utilising objective monitoring of physical activity for hip arthroscopy patients. Without the collection of more robust data to identify the type and quantity of activity undertaken, we are unable to

determine if patients are participating in sufficient physical activity to meet guidelines of minimal activity requirements for health.

The limited range of frequently used PROMs identified in the current review reflects the findings of Reiman et al. [8] and Renouf et al. [158]. Both these reviews identified that PROMs with appropriate clinimetric evidence to support their use in the population of young to middle-aged adults with hip-related pain and dysfunction, such as the iHOT-33 and the HAGOS, were utilised in less than 5% of studies assessing outcomes following hip arthroscopy and surgery for FAIS. The utility of the HOS-SS in this population has yet to be clearly established. In a recent review of PROMs for hip-related pain [20], the HOS was not recommended as it lacked content validity, an issue that likely also applies to the individual subscales. As Kemp et al. [21] also observed ceiling effects for the HAGOS-PA subscale, limiting its ability to identify improvements over time in hip-arthroscopy patients, further research is needed to identify which PROMs are best suited to capture physical activity gains in this cohort. PROMs that provide information on levels of activity, such as the HSAS and the Tegner were also infrequently utilised. The HSAS was assessed in four studies [6, 99, 118, 131], identifying no to moderate effect at 6 months [118, 131] and small effect sizes at approximately 2 years post-arthroscopy [6, 99]. Although the number of studies is limited, the smaller effect sizes may be indicative of less profound changes in relation to improvements in activity levels following surgery. Similarly, although only seven of the included studies sought to quantify the amount of activity undertaken in specific sports, the negative trends depicted indicate the importance of tracking more than one domain of physical activity. This is reiterated in the findings of Kierkegaard et al. [154], with the lack of agreement between objective and subjective reports of activity change. Only a quarter of the studies reported on the activity profile of participants, although information about the type of activity undertaken would be of value in identifying potential barriers and facilitators to physical activity participation post-arthroscopy.

This study offers insights into the effect of hip arthroscopy on physical activity, based on a comprehensive search strategy across eight databases utilising a rigorous screening and review process; however, there are a number of limitations that should be acknowledged. The methodological quality of the included studies was variable, many being retrospective studies with low participant numbers. This may increase potential for bias and magnification of positive effects [159]. Additionally, a number of studies were based on reviews of archived databases. The reliability of evidence emanating from these sources depends upon the quality of the database. National registries such as those developed in Sweden and Denmark, for which criteria, planning, monitoring and ongoing quality assurance are transparent [3, 160], provide data with high external validity. While single site/ single-surgeon registries offer a convenient tool for internal audit, the external validity and applicability of these data in the wider field are limited. When pooling study data in this review, a conservative approach was taken to data that were potentially derived from same database. While this reduced the number of studies contributing to the pooled data, it minimised the potential for data from the same participant to be duplicated in the analysis. It should be noted that in the visual representation of all HOS-SS outcomes, all studies were included. The high incidence of the HOS-SS may be an artefact of the number of studies emanating from North America and the dominance of a limited number of surgical centres, exacerbated by the omission of non-English language studies in this review. The predominance of North American studies also limits the cultural perspective of the data, with potential biases arising from influences on the manner in which participants complete patient-reported outcomes.

Conclusion

The current level of information regarding physical activity for post-arthroscopy patients is limited in scope. Within the framework of patients' perceived difficulties with sport-related activities, there is a consistent trend of post-arthroscopy improvement. However, the limited percentage of study participants achieving a score commensurate with 'feeling good', rather than 'feeling better', indicates a need for more in-depth analysis to identify potential barriers and facilitators, both physical and psychological, to achieving a more satisfactory return to physical activity.

Although the HOS-SS was the most frequently utilised PROM in this review, questions remain regarding its utility for this cohort. A greater range of outcome measures is needed to identify changes in other domains of physical activity. The use of objective measures, such as step count data, is currently a resource that is rarely utilised in studies, despite its use in contemporary practice, and warrants further investigation.

This review generates a compelling case for higher quality, sufficiently powered observational studies and RCTs. While RCTs remain the gold standard, purposefully designed, quality controlled, multicentre or population-level databases offer the opportunity for large-scale, comprehensive data collection. However, a more expansive view of physical activity profiles needs to be established with the routine collection of data about type and volume of

physical activity undertaken beyond the traditional focus on 'sport'-related physical activity.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s40798-020-0234-8.

Additional file 1: Example search strategy.

Additional file 2: Study quality assessment forms.

Additional file 3: Studies excluded at full text screen.

Additional file 4: Characteristics and outcomes of included studies.

Additional file 5: Overview of patient-reported outcomes identified in the review.

Additional file 6: Data from intermediate time points.

Additional file 7: Inclusion criteria, exclusion criteria, arthroscopic findings and interventions.

Additional file 8: Risk of bias assessment.

Abbreviations

PROMs : Patient-reported outcome measures; HAGOS-PA: The Copenhagen Hip and Groin Outcome Score-Participation in Physical Activities; HAGOS-SR : The Copenhagen Hip and Groin Outcome Score-Physical Function in Sport and Recreation; HOOS-SR : Hip disability and Osteoarthritis Outcome Score-Function in Sport and Recreation; HOS-SS: Hip Outcome Score-Sport Scale; HSAS: Hip Sports Activity Scale; iHOT-33 SR: International Hip Outcome Tool-Sports and Recreational activities; NAHS: Non-Arthritic Hip Score; HHS: Harris Hip Score; mHHS: Modified Harris Hip Score; Tegner: Tegner Activity Scale; UCLA: The University of California at Los Angeles activity score

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Not applicable

Authors' Contributions

All listed authors have made substantial contributions to the conception and design of the study. Literature search, acquisition of data and analysis were undertaken by DJ, KD, HH, JH, MO, JK and BM. The first draft of the manuscript was written by DJ. All authors were involved in the critical revision of the work and have read and approved the final version of the manuscript.

Authors' Information

Not applicable

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Availability of data and materials

Supporting data are supplied as electronic supplementary material and referred to within the script.

Ethics approval and consent to participate

Not applicable

Consent for Publication

Not applicable

Competing interests

Denise Jones, Kay Crossley, Ilana Ackerman, Harvi Hart, Karen Dundules, Michael O'Brien, Benjamin Mentiplay, Joshua Heerey and Joanne Kemp declare that they have no conflicts of interest relevant to the content of this review.

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Publisher's Note

PART B

OBJECTIVE MEASUREMENT OF PHYSICAL ACTIVITY

CHAPTER 4 : INTRODUCTION TO PART B

As identified in Chapter 2, although several potential measures exist, there is no single 'gold standard' measure of physical activity that can accurately capture the type, frequency, duration and intensity of activity while being unobtrusive, practical and cost-effective. For the quantitative assessment of free-living physical activity, accelerometry is a frequently used approach. Research-grade devices, such as the ActiGraph (Pensacola, FL 32502) have a substantial history of use in studies monitoring free-living physical activity[58, 158, 224]. In recent years, the consumer market has seen a dramatic influx of 'wearable activity trackers'[71] and these have been identified as a potential tool for research studies[59]. It is possible that the infrequent inclusion of objective measurement of physical activity, noted in Study 1 (Chapter 3)[111], might reflect the cost and operational complexity of using research-grade devices. Commercial activity trackers may offer a feasible alternative for researchers and study participants.

The Fitbit™ and the ActiGraph GT3X+ devices investigated in this section of the thesis are triaxial accelerometers recording motion in the anterior/posterior, medio-lateral and vertical planes. This triplanar record of motion provides an approximation of frequency, duration and intensity of physical activity. Such approximations are useful for the quantification, rather than qualification, of physical activity[26].

As can be seen from Figure 4.1, when assessing the output of devices, the assessment is primarily of the applied algorithms, rather than the mechanics of the device[163]. This is where substantial differences lie between 'research devices', such as the ActiGraph, where the applied algorithms are both transparent and clearly defined, compared with commercial devices where the algorithms are unknown to the user and protected by the manufacturers.

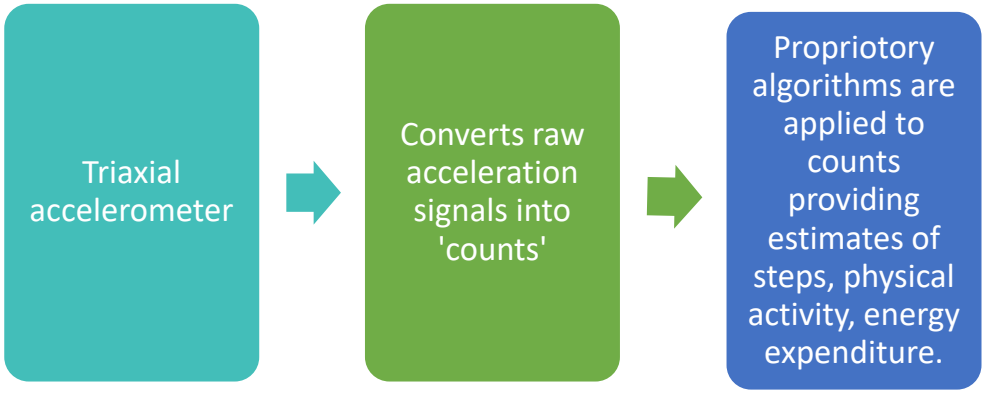

Figure 4.1 Flow of data conversion in triaxial accelerometers.

The raw acceleration data derived from the agitation of a piezoelectric element within accelerometers is converted into 'counts'[36]. When these 'counts' are averaged over a time period, this is referred to as an 'epoch'[26]. The raw output is then calibrated into some meaningful indicator of physical activity. Industry standards for the conversion of raw outputs do not exist and, as alluded to above, information about commercial algorithms is not available for comparison in a research setting.

Fitbit™ activity trackers dominated the commercial market until 2017/18 and remain one of the market-leaders[225], with evidence of increased use in clinical trials[61]. Post-hip arthroscopy activity data has relied predominantly on patient-reported outcomes. Use of Fitbit™ devices potentially provides a novel way to supplement quantitative physical activity data for this cohort.

Study 2 (Chapter 5)[110] and Study 3 (Chapter 6)[112] investigate the validity and reliability of the Fitbit™ devices in both a laboratory and a free-living setting.

The following information is included as appendices:

- Copies of ethical approval documents, patient information statement and informed consent, Study 2 and Study 3 – Appendix 3
- Copies of ethical approval documents, patient information statement and informed consent, Femoroacetabular impingement and hip OsteoaRthritis Cohort (FORCe) – Appendix 4
- Copies of ethical approval documents, patient information statement and informed consent, Physiotherapy for Femoroacetabular Impingement Rehabilitation Study (PhysioFIRST) – Appendix 5
- Copies of ethical approval documents, patient information statement and informed consent, Hip ARthroscopy Prospective Study – Appendix 6
- Example of additional information for use of Fitbit™ – Appendix 7
- Examples of recruitment advertising – Appendix 8

CHAPTER 5 (STUDY 2): VALIDITY AND RELIABILITY OF THE FITBIT FLEX™ AND ACTIGRAPH GT3X+ AT JOGGING AND RUNNING SPEEDS

A systematic review of the literature in Study 1 (Chapter 3) identified limited utilisation of objective measures, such as step count data, to inform our understanding of physical activity following hip arthroscopy. Additionally, no studies were identified using commercial activity trackers and their suitability for use in this patient group is unknown. The aim of this chapter (Study 2) was to evaluate the validity and reliability of the Fitbit Flex™, and the validity of a research-grade accelerometer, when measuring step count at jogging and running speeds, using a treadmill in a laboratory setting.

This chapter contains the following publication in its entirety:

Jones, D., Crossley, K., Dascombe, B., Hart, H. F. & Kemp, J. (2018) Validity and reliability of the Fitbit Flex™ and Actigraph GT3X+ at jogging and running speeds. *The International Journal of Sports Physical Therapy; 13*(5), 860-870. https://doi.org/10.26603/ijspt20180860

IJSPT

ORIGINAL RESEARCH

VALIDITY AND RELIABILITY OF THE FITBIT FLEX™ AND ACTIGRAPH GT3X+ AT JOGGING AND RUNNING SPEEDS

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ABSTRACT

Background: Monitoring levels of physical activity, as an outcome or in guiding rehabilitation, is challenging for clinicians. Personal activity monitors are increasing in popularity and provide potential to enhance rehabilitation protocols. However, research to support the validity and reliability of these devices at jogging and running speeds is limited.

Purpose: The purpose of this study was to evaluate the validity of the Fitbit Flex™ and ActiGraph GT3X+ for measuring step count at jogging and running speeds. A secondary purpose was to examine inter-device reliability of the Fitbit Flex™.

Study Design: Cross-sectional study

Methods: Thirty healthy participants aged between 19 and 50 years, completed a treadmill protocol at jogging and running speeds (8 km/h to 16 km/h). Treadmill speed was progressively increased by intervals of 2 km/h. Each interval was four minutes in duration with a two minute rest period between stages. Participants were encouraged to continue through the graded exercise test until they reached the maximum running speed that they felt they could maintain for four minutes. Step count data was collected for Fitbit Flex™ devices and the ActiGraph GT3X+. Video analysis of step count was used as the criterion measure.

Results: At speeds of 8 to 14 km/h Mean Absolute Percentage Errors were ≤1% for the Fitbit Flex™ and the ActiGraph GT3X+ when compared to step count via video analysis. Standard Error of Measurement between the three Fitbit Flex™ devices was ≤7 steps for speeds of 8 to 14 km/h and varied between 9 to 19 steps at 16 km/h. Fitbit Flex™ devices showed good to excellent between device reliability at speeds of 8 to14 km/h (ICC 0.723 to 0.999; $p \leq 0.001$). Greater variability was evident with the low participant numbers at 16 km/h (ICC 0.527 to 0.896; $p \geq 0.02$).

Conclusion: Both the Fitbit Flex™ and the ActiGraph GT3X+ provide a valid account of steps taken at jogging and running speeds up to 14 km/hr, attainable by non-elite runners on a treadmill. Fitbit Flex™ devices provide equivalent step count output to each other, enabling comparison between devices during treadmill jogging and running.

Level of evidence: 2b

Key words: Accelerometer, activity tracker, activity monitor, physical activity, step count

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INTRODUCTION

Physical therapists involvement in enabling and promoting physical activity is well established.[1] Enabling the maintenance, return to or improvement of physical activity levels as a key aim of therapy interventions aligns with the scope of practice descriptors identified by the World Confederation of Physical Therapy (WCPT).[2]

As physical activity is a primary factor associated with maintaining health and wellbeing, particularly when considering all-cause mortality,[3-5] it is undoubtedly an important outcome for athletes and non-athletes alike. Although injury has been shown to have a profound effect on long-term activity, irrespective on ongoing disability,[6] identifying suitable and user-friendly methods for monitoring and guiding physical activity is challenging for individuals, clinicians and researchers.

Step count is frequently used as an indicator of physical activity, the number of steps identifying a volume, rather than intensity of activity. Intensity may be extrapolated from the number of steps taken in a given time. It furnishes clinicians with a simple measure to provide guidelines and encourage behavior change for individuals and communities. This utility assumes that devices are reporting an appropriate account of steps taken. Evidence is currently lacking to substantiate the accuracy of step count output from devices in relation to more athletic populations.

Similarly, step count has been used to monitor post-intervention progress in individuals with a health condition, particularly where weight-bearing activity is a key healthcare outcome.[10-12] For runners, an accurate perception of the number of steps taken per minute may also be of relevance in relation to rehabilitation, such as attempting to increase step rate (cadence) to reduce patellofemoral load.[13] The increasing popularity of personal fitness trackers is indicative of individual enthusiasm for monitoring activity data. In addition, these trackers are serving to take the collection of objective physical activity data beyond the laboratory and into the public domain. The popularity of these devices provides opportunities for measuring physical activity that researchers and healthcare professionals are beginning to exploit. As with all emerging technologies, the purpose-specific utility of these devices needs to be established. Fitbit remains at the forefront of the market in digital fitness devices,[14] the Fitbit Flex™ being a popular wrist-worn device available at a relatively affordable price (~ USD$60).

Current research focuses on the validity of devices at lower speeds, which may be relevant for populations with chronic conditions that inhibit aerobic activity levels.[15-21] For clinicians working with sporting populations, and communities who are capable of running, these boundaries need to be expanded to evaluate the utility of devices at greater ambulation speeds. Correlation estimates of step count for the Fitbit Flex™ vary between studies. For speeds between 3 and 8 km/h, Diaz et al.[16] report strong correlations to criterion measure (0.77 to 0.85), conversely, Sushames et al.[21] report intraclass correlations of 0.05 and 0.34 for step count during walking and jogging respectively. Huang et al.[18] reported Mean Absolute Percentage Errors (MAPE's) of 6.5% and 8.9% for the Fitbit Flex™ at treadmill speeds of 3.24 and 6.41 km/h, respectively. During combined walking and jogging, Nelson et al.[22] reported a comparable MAPE of 6%. Although study protocols vary, a tendency for the Fitbit Flex™ to underestimate step count is evident, this effect being more pronounced at slower speeds.[15,16,18,21] Data is limited to substantiate the performance of the Fitbit Flex™ at speeds above 8 km/h. Therefore, this study investigated the validity of the Fitbit Flex™ at jogging and running speeds by assessing accuracy of the device output in relation to observed values for step count. Inter-device reliability was assessed by evaluating the precision of output between Fitbit Flex™ devices over the same range of jogging and running speeds. In comparison to commercially available activity trackers, the ActiGraph GT3X+ is a research grade device which allows access to underlying algorithms and options for the user in converting raw count data to step count and energy expenditure data. It is frequently used as a comparator to commercially available devices in assessing physical activity.[23-27] Simultaneous investigation of the Fitbit and ActiGraph devices was undertaken to provide comparative measures to aid assessment of their relative merits for researchers.

The purpose of this study was to evaluate the validity of the Fitbit Flex™ and ActiGraph GT3X+ for measuring step count at jogging and running speeds. A secondary purpose was to examine inter-device reliability of the Fitbit Flex™. The results of this study provide an objective measure of interest to the running community using the Fitbit Flex™ for personal activity monitoring and guidance for clinicians wishing to utilize these devices within rehabilitation and maintenance programmes, such as implementing graded return from injury or embedding modifications to running step rate to modify joint loading.

METHODS

Participants

Thirty young and middle-aged healthy adults were recruited for this cross-sectional study. Participants were recruited within the university and the wider community via website postings, social media, and word-of-mouth. The study was approved by La Trobe University Human Ethics Committee (Approval number HEC16-082).

Eligibility criteria

The Physical Activity Readiness Questionnaire (PARQ) was used to screen for safe participation. Potential participants were excluded on the basis of acute or chronic health conditions that precluded running activity, being pregnant, breastfeeding, being outside the age range of 18 to 50 years or lacking sufficient English language skills to give informed consent.

Equipment

ActiGraph

The ActiGraph GT3X+ (ActiGraph, Pensacola, FL) is a small (4.6 x 3.3 x 1.5 cm), lightweight (19g) tri-axial accelerometer (Figure 1A). It was worn on an elastic belt below the waist, in line with the right anterior axillary line and did not impede the participants' ability to run.

Fitbit

The Fitbit Flex™ (Fitbit Inc., San Francisco, CA) is a consumer-wearable activity tracker. The triaxial accelerometer is held within a wristband providing a five-light LED display of activity progress (Figure 1B).

Protocol

Data collection took place in a non-air-conditioned physiology laboratory at La Trobe University, Melbourne, Australia, between December 2016 and February 2017. Prior to undertaking testing, potential participants were offered further information on the study and screened for eligibility. All participants

Figure 1. *A. ActiGraph GT3X+ (With permission, Actigraphcorp.com); B. Fitbit FlexTM (With permission, fitbit.com)*

gave written, informed consent prior to undertaking the test.

Self-reported measures of body mass (kg) and height (m) were used where recent accurate measures could be offered by participants. Where any queries arose, measurements were confirmed in the testing laboratory using a stadiometer and digital scales. Body mass index (BMI) was calculated from these measures.

Participants were advised to wear suitable sports clothing and footwear for the test and abstain from alcohol, caffeine, and cigarettes for 24 hours prior to the test. Participants were also advised to avoid a large meal for at least three hours prior to testing and avoid vigorous exercise during the 24 hours prior to testing in line with standard recommendations for maximal exercise testing.[28]

Prior to use by each participant the ActiGraph GT3X+ devices were initialized via the supporting software (Actilife 5.10.0, ActiGraph, Pensacola, FL) inputting: start time; sampling rate (30Hz); device position; date of birth; sex; body mass; height and race of the participant.

Each participant was fitted with three Fitbit Flex™ devices, two on the left wrist (device numbers 1 and 2) and one on the right wrist (device number 3). Each band was securely fitted to the participant's wrist to allow minimal movement during testing without being uncomfortable.

For each Fitbit Flex™ device participants' demographic data (sex, date of birth, height, body mass, walking and running stride length) were entered, via the web Fitbit interface. Fitbit defines a stride as heel strike to heel strike of the opposite foot, more conventionally defined as a step. This was assessed for individual participants with a measured 10-step walk in a straight line over flat ground. The process was repeated at a comfortable running pace, self-selected by the participant. The distance was then divided by a factor of 10 to give an average 'stride'/step length.

For the purposes of treadmill testing, participants were deemed to be undertaking a standardized activity with relatively symmetrical arm movement. Due to this bilateral equivalence, all the Fitbit Flex™ devices were maintained at the default setting of 'non-dominant' throughout all data collection.

To obtain minute level data from the Fitbit Flex™ devices, each device was placed into 'activity mode' by tapping the device sharply (1 to 2 sec) until it vibrated. The activity mode was deactivated at the end of each test by repeating this procedure. This allowed for a discrete set of minute-by-minute data to be viewed via the interface.

At the start of each test session, participants were given a warm-up period of five minutes on the treadmill (Cosmed T200, Rome, Italy) to familiarize them with the equipment and ensure that all devices were comfortable and secure. Participants then undertook two further warm-up periods at 4 and 6 km/h for four minutes at each level, separated by two minutes rest, to familiarize them with the treadmill protocol. Participants were advised to maintain their regular arm swing, avoid looking at the devices and to avoid holding on to the treadmill.

The graded exercise test began at 8 km/h, progressing at 2 km/h intervals. Each interval was four minutes in duration with a rest period of two minutes between each interval. Rest periods facilitated transitions and the tracking of data between devices. Intervals were recorded for video analysis of step count. A video camera (Lumix DMC-FZ2000, Panasonic, UK) was placed to capture right and left footfall during each incremental stage of a test. A clearly visible digital clock was placed within the video frame to enable tracking of real time. Data from devices were compared to video observation of step count, which was regarded as the criterion measure.

Participants were encouraged to continue through the graded exercise test until they reached the maximum running speed that they felt they could maintain for four minutes. Each test was terminated either at the participant's request or at a point at which the researchers had concerns for the participant's wellbeing.

Data Processing

Following test sessions, each Fitbit Flex™ was synced to allow the data to be accessed via the product interface. Data from each ActiGraph GT3X+ was downloaded via a universal serial bus (USB) and processed using proprietary software (Actilife 5.10.0, Actigraph Corp. Pensacola, FL). The data

were processed in 60-second epochs to align with the output from the Fitbit Flex™.

Videos were downloaded to a PC and viewed via Windows Media Player. The recordings (30 frames per second) were visually analyzed in slow motion and the number of steps, identified by foot strike, tallied for the middle two minutes of each level completed by the participant. The middle two minutes of each stage was used to minimize inconsistencies related to participants settling into their target pace or becoming fatigued at the termination of later stages The observed video data provided criterion values for step count at each level of the treadmill test. A proportion (10%) of the step count data was analyzed by two assessors (DJ and SC) to ensure consistency.

Analysis

Sample size

Sample size numbers were determined by procedures described by Walter et al.[29] for inter-device reliability. Twenty two subjects were deemed to be acceptable to judge the difference between two devices with a minimally acceptable level of 0.5, when $\alpha = 0.05$ and $\beta = 0.20$ (power = 0.08). A sample size of 18 participants was required to assess validity of the devices based on an estimated correlation coefficient of r = 0.6, 2 tailed test ($\alpha_2 = 0.05$) with a power of 80%.[30]

Inter-device reliability

Inter-device reliability was determined for the three Fitbit Flex™ devices using intraclass correlation coefficients (ICC 2, 1)[30] with 95% confidence intervals (CI). ICC's were considered to be excellent (0.75 and 1.00); good (0.60 and 0.74); fair (0.40 and 0.59) or poor ($\leq$0.40).[31] Paired *t*-tests ($\rho = 0.05$) were performed on normally distributed data to determine the mean difference (group mean difference) between devices. The standard error of measurement (SEM) was calculated for normally distributed data to determine absolute reliability. This was calculated using the formula SEM = Standard deviation (SD) x $\sqrt{1}$-ICC.

Validity

Validity was evaluated for the Fitbit Flex™ and ActiGraph GT3X+ for step count, by comparing to observed step count. Correlations between device and criterion measure were judged on the following guidelines for correlation coefficient (r): Little or no relationship (0.00 to 0.25); fair relationship (0.25 to 0.50); moderate to good relationship (0.50 to 0.75) and good to excellent relationship (above 0.75).[30]

To further investigate device validity, MAPE was used to provide a conservative estimate of individual level error.[32] MAPE is calculated with the following formula:

$$\frac{\text{Absolute bias (criterion – device)}}{\text{Criterion}}$$

Limits of agreement were used to show the spread of the difference of scores.

The significance criteria for all tests was $\alpha = 0.05$ and $\beta = 0.20$, thus power = 0.8 (1-β), and confidence intervals were 95% (1-α).

RESULTS

Participant characteristics

Between November 2016 and February 2017, 54 potential participants responded to notification and advertisement of the study. Figure 2 summarizes the flow of respondents through the study. Thirty healthy adults (18 women, 12 men; mean $\pm$ SD: age, 33 $\pm$ 8 years; BMI, 24.1 $\pm$ 2.5 kg/m^2) were included in the study (Table 1).

Findings

All 30 participants completed the protocol to the end of 8 km/h. As the speed increased above 8 km/h, there was a decrease in the sample number (Figure 3). Baseline characteristics of participants completing each level are outlined in Table 2. ActiGraph GT3X+ data were successfully obtained for all 30 participants and minute by minute data were successfully collected for all three of the Fitbit devices worn for 20 participants. For the remaining ten participants, data from two Fitbit Flex™ devices were successfully collected for seven participants. For one participant minute data was successfully collected from only one of the Fitbit devices. Two participants were missing all minute by minute data from the Fitbit Flex™ devices. The missing data was the result of errors in setting the devices to activity

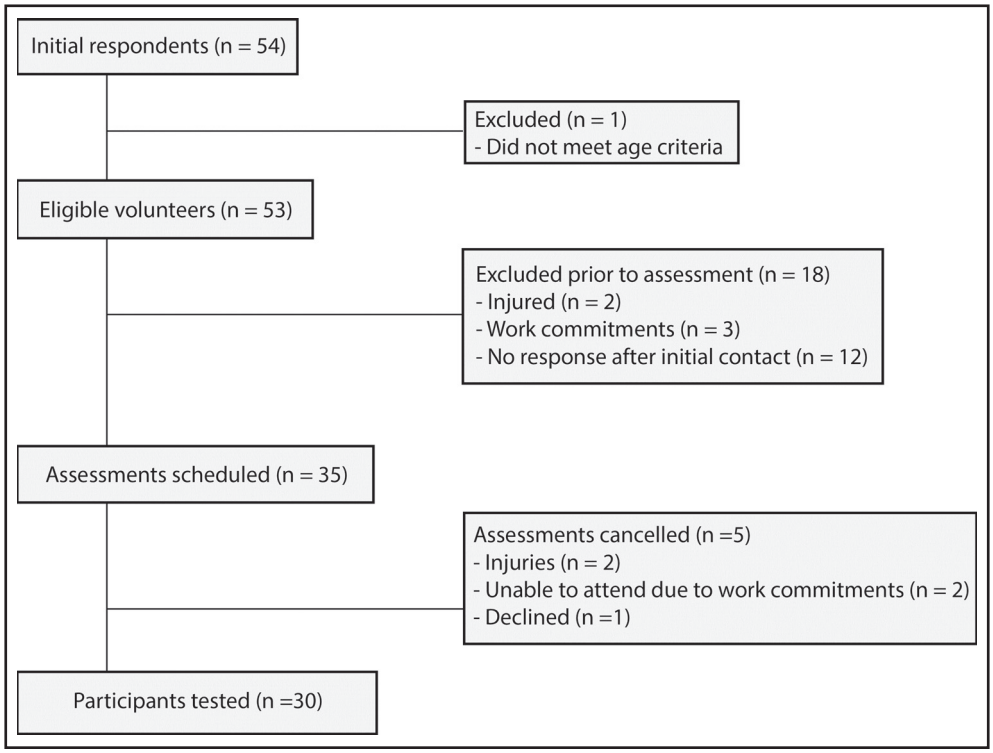

Figure 2. *Flow chart showing the number of respondents and reasons for drop-out.*

Table 1. *Demographic characteristics of the study cohort.*

Characteristics	Total Mean (SD) range n = 30	Women Mean (SD) range n = 18	Men Mean (SD) range n = 12
Age (years)	33 (8) 19 - 50	34 (7) 19 - 46	32 (8) 23 - 50
Height (m)	1.71 (0.12) 1.47 - 1.95	1.64 (0.07) 1.46 - 1.76	1.82 (0.10) 1.61 - 1.95
Body Mass (kg)	71 (16) 44 - 128	62 (8) 44 - 74	83 (16) 68 - 128
BMI (kg/m^2)	24.07 (2.51) 19.43 - 33.53	23.19 (1.77) 19.43 - 26.50	24.99 (3.13) 21.83 - 33.53

SD = +/- 1 Standard deviation; n = number of participants; m = meters; kg = kilogram; BMI = body mass index

mode. The successful functioning of this mode for the duration of the test could not conveniently be checked until the data were downloaded and viewed following completion of the trial. For seven participants, errors occurred in video records. A total of eight two-minute intervals were, therefore, missing observed step count analysis. Due to the missing data, sample size varies throughout areas of data analysis and is reported accordingly.

Observed step count, inter-rater reliability

When comparing video analysis observed step count, inter-rater reliability between both testers was excellent (ICC = 1.000, 95% CI 0.999 to 1.000).

Inter-device reliability

The three Fitbit Flex™ devices demonstrated excellent between device reliability for step count for speeds of 8 to14 km/h (Table 3), with the exception

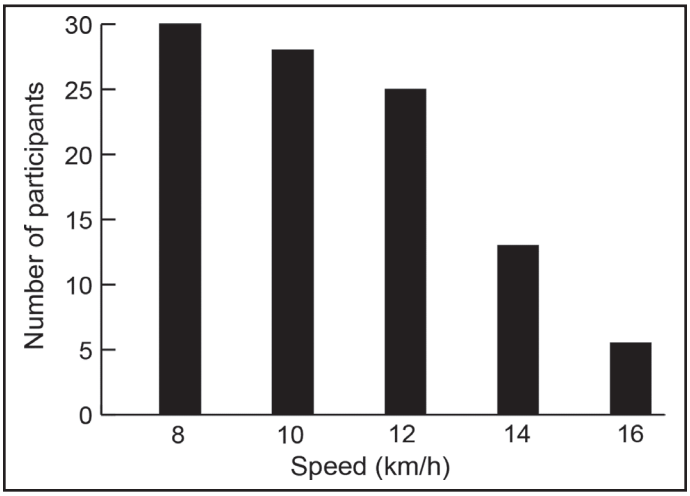

Figure 3. *Number of participants completing each level of treadmill testing.*

of Fitbit Flex™ 2 (left arm) and Fitbit Flex™ 3 (right arm) at 12 km/h, for which the intraclass correlation was good (ICC (2,1) 0.723, 95% CI 0.370 to 0.894).

The SEM between the two devices on the same arm did not vary by more than 1% at speeds of 8 to 14 km/h. This error increased to a maximum of 2% between the right and left arm devices for these speeds. Greater errors were evident at 12 km/h. A similar trend is observed at 16 km/h with SEM varying by less than 3%, at both speeds, for devices on the same side and less than 6% for devices on opposite arms.

Validity

Due to the close correlation of the output between Fitbit devices, Fitbit Flex™ 1 (left wrist) and the ActiGraph GT3X+ were assessed against the criterion measures of observed step count. Correlations between Fitbit Flex™ 1 and observed step count from video analysis were excellent for speeds of 8 to 14 km/h (Table 4). A fair relationship was evident at 16 km/h. Correlations between the ActiGraph GT3X+ and observed step count were excellent for all levels of the test, $r \geq 0.905$ for speeds of 6 to 14 km/h (Table 4). The MAPE values were <1% for both the ActiGraph GT3X+ and the Fitbit Flex™ across all reported speeds.

DISCUSSION

This study evaluated Fitbit Flex™ inter-device reliability and validity of the Fitbit Flex™ and ActiGraph GT3X+ in a healthy cohort of men and women aged 18 to 50 years. It compared the output from the Fitbit Flex™ and ActiGraph GT3X+ to the criterion measure of observed step count over speeds ranging from 8 to 16 km/h. The results indicate that both the Fitbit Flex™ and the ActiGraph GT3X+ provide a valid assessment of step count with close correlation to observed step count and MAPE values below 1% for speeds of 8 to 14 km/h.

Fitbit Flex™ inter-device reliability was excellent for devices worn on the same arm with closely associated absolute measures at speeds of 8 to 14 km/h. The low SEM between all three Fitbit devices for speeds of 8 to 14 km/h (1 to 4 steps), indicates a high level of confidence that output from the Fitbit Flex™ devices is equivalent. The large confidence intervals observed for mean differences between devices at 16 km/h highlights that participant numbers were

Table 2. *Characteristics of participants completing different levels of the test.*

Speed (km/h)	n	Men/Women	Age (Years) Mean (SD)	Height (m) Mean (SD)	Body Mass (kg) Mean (SD)	BMI (kg/m^2) Mean (SD)
8	30	12/18	34 (8)	1.71 (0.12)	71 (16)	23.80 (7.64)
10	28	12/17	33 (8)	1.72 (0.12)	71 (15)	23.95 (2.41)
12	25	11/14	33 (8)	1.72 (0.12)	70 (11)	23.66 (1.59)
14	13	8/4	34 (8)	1.77 (0.10)	75 (8)	23.83 (1.47)
16	6	5/1	34 (9)	1.80 (0.09)	77 (9)	23.72 (0.82)

km = kilometres; h = hour; n = number of participants; SD = +/- 1 Standard deviation; m = meters; kg = kilogram; BMI = body mass index

Table 3. *Fitbit Flex™ inter-device reliability for step count. Fitbit Flex™ 1 and Fitbit Flex™ 2 worn on the left wrist, Fitbit Flex™ 3 on the right wrist. Mean difference was generated from paired sample t-tests, p-value ≥0.05 indicates that output from devices does not differ significantly.*

	DEVICES	SPEED 8 KM/H	SPEED 10 KM/H	SPEED 12 KM/H	SPEED 14 KM/H	SPEED 16 KM/H
Step count Mean (SD) n	FBF 1	318 (16) 27	331 (20) 25	335 (30) 23	347 (21) 11	345 (27) 6
	FBF 2	318 (17) 21	332 (19) 19	339 (19) 17	352 (19) 8	350 (22) 4
	FBF 3	319 (15) 26	332 (19) 24	339 (30) 22	344 (20) 12	350 (18) 6
	Observed	318 (16) 27	331 (21) 26	342 (21) 24	346 (23) 10	356 (20) 5
Mean difference in step count between FBF devices (95% CI) DoF p-Value*	FBF 1 and 2	1 (0 to 2) 19 0.100	0 (0 to 1) 17 0.138	1 (-1 to 2) 15 0.542	1 (-1 to 2) 6 0.200	-3 (-23 to 18) 3 0.701
	FBF 1 and 3	1 (0 to 2) 19 0.100	1 (0 to 2) 22 0.044	-3 (-8 to 1) 20 0.137	0 (-1 to 2) 10 0.553	-5 (-29 to 19) 5 0.608
	FBF 2 and 3	0 (-1 to 0) 19 0.428	1 (-1 to 2) 17 0.284	-4 (-11 to 3) 15 0.270	1 (-1 to 2) 7 0.516	-8 (-30 to 13) 3 0.298
Standard error of measurement between FBF devices (step count)	FBF 1 and 2	1	1	4	1	9
	FBF 1 and 3	1	1	7	2	19
	FBF 2 and 3	1	2	1	2	12
ICC (95% CI) p- Value	FBF 1 and 2	0.994 (0.986 to 0.998) <0.001	0.999 (0.997 – 1.000) <0.001	0.986 (0.961 to 0.995) <0.001	0.996 (0.976 to 0.999) <0.001	0.896 (0.083 to 0.993) 0.020
	FBF 1 and 3	0.997 (0.994 to 0.999) <0.001	0.996 (0.990 to 0.998) <0.001	0.953 (0.887 to 0.981) <0.001	0.995 (0.983 to 0.999) <0.001	0.527 (-0.378 to 0.917) 0.112
	FBF 2 and 3	0.998 (0.994 to 0.999) <0.001	0.994 (0.985 to 0.998) <0.001	0.723 (0.370 to 0.894) <0.001	0.994 (0.971 to 0.999) <0.001	0.721 (-0.429 to 0.979) 0.085

SD = +/- 1Standard deviation; CI confidence interval; DoF – degrees of freedom; *(2-tailed sig.); ICC = Intraclass Correlation Coefficient; n = number of participants; km/h = kilometres per hour; FBF 1, FBF 2, FBF 3= Fitbit Flex™ devices 1,2 and 3; Statistically significant at p < 0.05.

Table 4. *Validity of devices to criterion measure. Correlation of Fitbit Flex™ 1 and ActiGraph GT3X+ to observed step count and percent agreement to observed step count for Fitbit Flex™ and ActiGraph GT3X+, calculated as Mean Absolute Percentage Error (MAPE).*

SPEED	OBSERVED STEP COUNT		FITBIT FLEX™						ACTIGRAPH GT3X+					
km/h	*Mean±SD*	*n*	*Mean±SD*	*n*	*r (p-value)**	*n*	*MAPE (%)*	*ULOA (%)*	*LLOA (%)*	*Mean±SD*	*n*	*r (p-value)**	*n*	*MAPE (%)*	*ULOA (%)*	*LLOA (%)*
8	318±16	27	318±16	27	0.997 (<0.001)[1]	25	0	1	0	318±15	29	0.997 (<0.001)[1]	27	0	1	0
10	331±21	26	331±20	25	0.994 (<0.001)[1]	24	1	1	-1	331±20	27	0.998 (<0.001)[1]	26	0	1	0
12	342±21	24	335±30	23	0.829 (<0.001)[1]	22	1	7	-5	338±28	25	0.990 (<0.001)[1]	24	1	2	-1
14	346±23	10	347±21	11	0.999 (<0.001)[1]	9	0	0	1	341±19	13	0.905 (<0.001)[1]	10	1	6	-4
16	356±20	5	345±27	6	0.409 (0.494)	5	4	19	-11	350±19	6	0.762 (0.134)	5	2	9	-6

* correlation to observed step count; *km/h* = kilometres per hour *SD* = +/- 1Standard deviation; *n* = number of participants; *r* = Pearson's r for parametric data; *MAPE* = Mean Absolute Percentage Error; *ULOA* = upper limit of agreement; *LLOA* = lower limit of agreement; [1]Statistically significant at p < 0.05

insufficient to draw conclusions regarding reliability of the Fitbit Flex™ devices at this speed. The relatively symmetrical upper limb activity expected with treadmill walking and running was reflected in the similarity of mean differences between devices on opposite sides. Greater variances evident in right/left data at 12 km/h reflect one outlying set of data. With this participant omitted from analysis, ICC's for Fitbit 1 and 3 improve from 0.953 to 0.995 ($p < 0.001$) and Fitbit 2 and 3 from 0.723 to 0.981 ($p < 0.001$).

In previous studies of the Fitbit Flex™, MAPE's have varied. Both Diaz et al.[16] and Sushames et al.[21] reported

a trend of improvement as assessed treadmill speeds increased. Diaz et al.[16] reported a MAPE of 16% at 3 km/h improving to 1.8% at 8.4 km/h. Sushames et al.[21] observed self-selected walking speeds (between 5 and 6.5 km/h) and jogging speeds (between 8 and 10 km/h) with MAPE decreasing from 14.7% to 2.5% at higher speeds. Conversely, Huang et al.[18] reported an increase of 2.4% in MAPE's between 3.2 and 6.4 km/h. Findings in the current study are reflective of these previously reported figures at 8 to 10 km/h, additionally, the current study highlights that low MAPE's are also associated with speeds above those previously reported. The excellent correlations between Fitbit Flex™ 1 and observed step count from video analysis indicate a valid measure. With only five participants, it is inappropriate to draw conclusions regarding the relationship between the devices and criterion measure at 16 km/h.

Despite the ability to use filters to accommodate for slow speeds, studies of the ActiGraph GT3X+ mirror the trends seen in Fitbit Flex™ data with poor correlation to step count criterion measures at slow speeds, improving as more standard walking speeds are reached.[33,34] However, Tudor-Locke et al.[35] concluded that steps estimated by a waist-worn ActiGraph GT3X+ were not significantly different from observed step count in speeds ranging from 0.84 km/h to 11.28 km/h. The current study expands the pool of data available for the ActiGraph GT3X+, including previously unreported running speeds above 11 km/h. Correlations to observed step count for jogging and running speeds the current study, ranging from 0.905 to 0.990 ($p < 0.001$), reflect those reported by Lee et al.[34] for average walking speeds. These correlations are markedly different to those reported by Sushames et al.[21] for jogging (0.46, $p = 0.005$). Differences in methodology, such as the self-selection of jogging speed and the 6-minute duration of data collection may account for some of the differences observed.

For research purposes, commercial devices such as the Fitbit Flex™ potentially have substantial advantages in relation to cost; subjective perceptions of the device, such as being more agreeable to wear, and therefore compliance from participants. Their utility may be compromised by their commercial nature and the speed of change in the market. The Fitbit Flex™ assessed in this study had now been superseded by the Fitbit Flex2™. For researchers, this means that the pool of evidence underpinning data collection will remain limited for specific devices and that restricted information sharing from commercial producers will prevent researchers being able to give a full account of algorithms and accuracy when reporting their findings. Small-scale studies such as this can provide a compromise to mitigate some of the uncertainty of using commercial devices. Changes in the commercial market have less impact on clinical utility of devices which maintain the advantages of being accessible, affordable and broadly equivalent to previous incarnations of the same device in relation to the accuracy of basic algorithms such as step count.

LIMITATIONS

There are a number of limitations in this study that should be acknowledged. First the convenience sample of participants for this study encompassed a range of athletic abilities across a young and middle-aged cohort of healthy adults. The non-elite nature of the runners participating limited the number able to sustain speeds above 12 km/h. Lower participant numbers at 14 and 16 km/h compromises the validity of the findings at these speeds. A larger pool of participants would reduce the effect of outlying data such as that identified at 12 km/h. Additionally, utilizing laboratory-based measures of height and body mass for all participants would be recommended for future studies to eliminate the possibility of any inaccuracies, particularly in relation to more elite sporting populations. Second, minute by minute data for step count cannot be accessed via the Fitbit user interface unless the device has been put into an activity mode. This resulted in the loss of some data where the activity mode failed to activate or was inadvertently deactivated during the running trials. Third, the two-minute intervals reported provide a limited snap-shot of activity related to controlled treadmill running conditions. The results should be interpreted with caution as they cannot be extrapolated to be indicative of the performance of the devices over the range of running surfaces and physical activity occurring in free-living. Future research in less restrained conditions, using runner specific populations, would be a valuable addition to the current knowledge base.

CONCLUSIONS

Both the Fitbit Flex™ and the ActiGraph GT3X+ provide a valid account of steps taken at jogging and running speeds attainable by non-elite runners on a treadmill. Inter-device reliability for step count at jogging and running speeds indicates that individual users the Fitbit Flex™ can compare outputs between each other's devices for these activities with relative confidence. Users of these devices should be advised to wear the device on the same arm to provide the most reliable comparison of day-to-day data.

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CHAPTER 6 (STUDY 3): WHAT IS THE AGREEMENT BETWEEN TWO GENERATIONS OF COMMERCIAL ACCELEROMETER IN A FREE-LIVING ENVIRONMENT FOR YOUNG TO MIDDLE-AGED ADULTS?

Study 2 (Chapter 5) established that the Fitbit Flex™ offered a valid account of steps taken at jogging and running speeds within a controlled environment; however, this did not consider the practicality of using commercial accelerometers to collect data in a free-living environment. The aim of this chapter (Study 3) was to establish the level of agreement between two generations of a Fitbit™ device (Flex™ and Flex 2™) for step count and activity minutes undertaken by healthy young to middle-aged adults in a free-living environment. Secondary aims were to evaluate the number of days of step count data retrieved from the two grades of device over a two-week period and report relative output of step count for the two grades of device in this cohort.

Jones, D., Hart, H., Crossley, K., Ackerman, I. & Kemp, J. (2019). What is the agreement between two generations of commercial accelerometer in a free-living environment for young to middle-aged adults? *Journal for the Measurement of Physical Behaviour, 2*, 49-57. https://doi.org/10.1123/jmpb.2018-0064

CHAPTER 7 (STUDY 4): A PROOF OF CONCEPT STUDY UTILISING STEP COUNT TO COMPARE PHYSICAL ACTIVITY BETWEEN SURGICAL AND NON-SURGICAL PATIENTS WITH HIP-RELATED PAIN AND HEALTHY CONTROLS

7.1 ABSTRACT

Purpose:

The aims of this proof of concept study were to: (1) utilise commercial accelerometers to compare mean daily step count, as a proxy measure for physical activity, for four groups of participants sited at different points on the spectrum of hip disease, from healthy controls to post-arthroscopy; (2) describe differences in hip-related quality of life between the symptomatic groups; (3) utilise commercial accelerometers to observe mean daily step count in people who were approximately three months, six months and one year post-hip arthroscopy; and (4) explore the limitations of collecting valid daily step count data for a) a single episode of data collection at baseline and b) repeated episodes of data collection.

Methods:

A cross-sectional analysis of step count data was undertaken for 116 participants (aged 18 to 50 years) comparing healthy controls and three groups of people with hip-related pain: football players, individuals with femoroacetabular impingement (FAI) syndrome and post-hip arthroscopy patients. Regression analysis was used, accounting for age and sex. The 33-item International Hip Outcome Tool (iHOT-33) was used to quantify hip-related quality of life. The influence of the participant group on achieving a patient-acceptable symptom state (PASS) for the iHOT-33 was examined using binomial logistic regression. Mean daily step count data were gathered from 46 participants post-arthroscopy. Available data from these participants were compared for time points at approximately three months, six months and one-year post-arthroscopy. Return of valid step count data was determined for the first episode of data collection (baseline data for all groups) and subsequent time points (post-arthroscopy group only).

Results:

No significant difference was evident in the mean daily step count between the four groups (p=0.558) after adjusting for age and sex. Group was not predictive of reaching the PASS for the iHOT-33 for symptomatic groups when age and sex were accounted for (p=0.296). Mean daily step count showed little variation between data collected at approximately three months, six months and one year following hip-arthroscopy (ranging from (mean±standard deviation) 8129±2019 to 9169±3081 steps per day). Successful retrieval of 95% of step count data from commercial accelerometers was achieved for cross-sectional data and approximately 75% of subsequent data collection.

Conclusion:

An objective measure of physical activity, operationalised as step count, did not differ between healthy controls, individuals with hip-related pain participating in competitive football, individuals with FAI syndrome and post-hip arthroscopy patients. Equivalent hip-related quality of life scores were reported by symptomatic groups across a spectrum of hip disease, pre- and post-surgery. Commercial accelerometers offer a valid and feasible alternative to research-grade accelerometers for assessing step count in young to middle-aged adults with hip-related pain.

7.2 Introduction

Hip-related pain has a range of presentations in young to middle-aged adults, with the level of physical activity restriction and treatment choices potentially reflecting symptom and disease severity. Individuals may continue to participate in their desired sporting or physical activity pursuits despite experiencing pain, seek non-surgical management options or perceive their symptoms and restrictions to be of sufficient severity to undergo surgery. Maintaining participation in physical activity, including sporting pursuits, is a key motivator for individuals with hip-related pain, these goals being among the most notably cited as reasons for undergoing arthroscopic hip surgery[151, 152].

The impact of hip-related pain and arthroscopic surgery on physical activity is unclear. A cross-sectional study comparing asymptomatic controls and pre-hip arthroscopy patients[87] identified significant stride, and therefore step, count differences between asymptomatic and symptomatic individuals; however, when subgroups with defined pathologies were analysed, the distinctions were less clear cut. Participants with FAI syndrome and developmental dysplasia of the hip averaged a similar number of strides to asymptomatic individuals, despite symptoms being of sufficient severity to warrant surgery. Despite this parity in step count, reductions in self-reported physical activity have been reported for pursuits such as swimming[67], cycling[68], running[146], high-intensity interval training[206] and dancing[245] in individuals awaiting hip-arthroscopy.

Monitoring physical activity as an outcome following interventions for hip-related pain has primarily been undertaken thus far using patient-reported outcome measures (PROMs)[111, 127, 221]. After hip-arthroscopic surgery, there is consistent improvement in patient-perceived physical function (Study 1)[111]; however, where objective physical activity data have been gathered using accelerometry, alongside self-assessment of physical activity, inconsistencies are evident. In young to middle-aged individuals undergoing hip arthroscopy for FAI syndrome[131] or periacetabular osteotomy for hip dysplasia[107], accelerometry-measured physical activity did not reflect the self-reported improvements in hours of weekly activity nor the subjective assessment of improved physical function. This result implies that perceived physical function and objectively measured physical activity are distinct, or only partially related, constructs[221]. As such, objective monitoring of physical activity is a vital adjunct in comprehensively assessing the outcomes of interventions for hip-related pain. Capturing a complete picture of physical activity is challenging; however, the assessment of step count provides a simple, consistent metric that illustrates a fundamental component of weight-bearing activity[15], has established associations with physical health variables[15, 138, 240] and can be interpreted to classify activity categories[242].

To date, only research-grade accelerometers have been used to objectively measure physical activity in cohorts of young to middle-aged adults undergoing hip surgery[107, 131] and no studies have used accelerometry as an objective measure of physical activity in cohorts undergoing non-surgical interventions for hip-related pain[127]. Commercial accelerometers (also known as fitness trackers, activity trackers or personal activity monitors), such as Fitbit™ devices, have been used in older populations undergoing total hip arthroplasty[250], but their utility has yet to be explored in the context of young to middle-aged adults with hip-related pain and higher physical activity demands.

The aims of this proof of concept study were to: (1) utilise commercial accelerometers to compare mean daily step count, as a proxy measure for physical activity, for four groups of participants sited at different points on the spectrum of hip disease, from healthy controls to post-arthroscopy; (2) describe differences in hip-related quality of life between the symptomatic groups; (3) utilise commercial accelerometers to observe mean daily step count in people who were approximately three months, six months and one year post-hip arthroscopy; and (4) explore the limitations of collecting valid daily step count data for a) a single episode of data collection at baseline and b) repeated episodes of data collection. We hypothesised that adults with hip-related pain would have a lower mean daily step count than healthy controls.

7.3 METHODS

7.3.1 Study design and ethical approval

This study is comprised of two components. Firstly, a cross-sectional comparison of data (study aims 1 and 2) was conducted using four groups (Group 1 - healthy controls; Group 2 (FORCe) - football players with hip-related pain maintaining participation in training and competition; Group 3 (PhysioFIRST) - individuals with hip-related pain, diagnosed with FAI syndrome, seeking physiotherapy treatment; and Group 4 (HARP) - individuals approximately one year after hip arthroscopy (as identified in Figure 7.1). Secondly, we conducted a comparison of mean daily step count at approximately three months, six months and one year for the post-hip arthroscopy group (Group 4) (study aim 3). The percentage of valid daily step count data returned was considered across both components (study aim 4). The studies were approved by La Trobe University Human Ethics Committee (Healthy controls, HEC16-082; FORCe, HEC 15-019; PhysioFIRST, HEC17-080; HARP, HEC-137) and all participants gave written informed consent. Readers are referred to the published protocols for each study for more in-depth information on study groups[44, 125, 207].

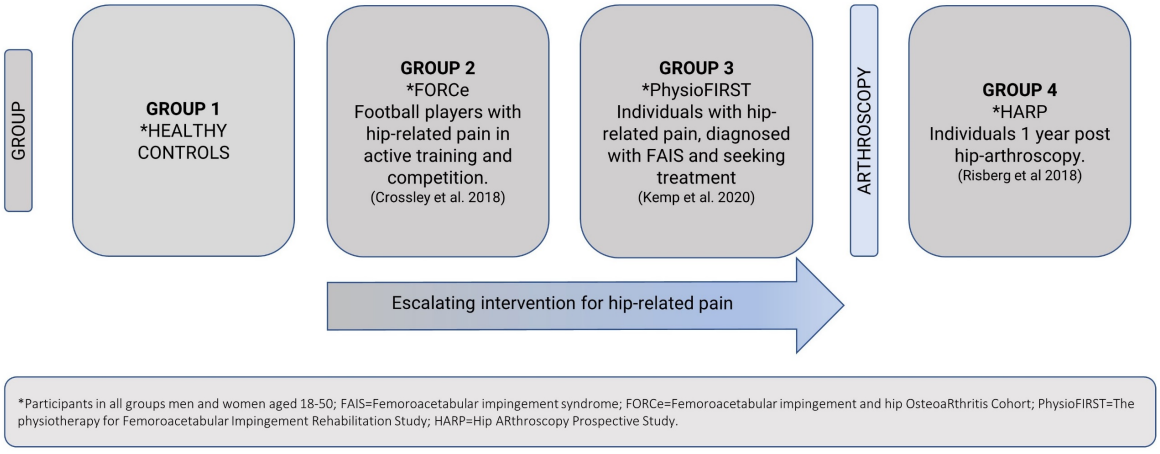

Figure 7.1 Relationship of study groups to level of intervention for hip-related pain.

7.3.2 Participants and recruitment

All participant groups were based in Australia. Inclusion criteria for each cohort are detailed in Table 7.1. For the current study, participants were required to be aged between 18 and 50 years with access to a suitable device (smartphone, tablet or computer) on which to set up the Fitbit™ application. Additionally, participants needed to be free of restrictions that precluded them from wearing the Fitbit™ device during their normal working day. No restrictions were placed on sport participation type or level, except for participants in Group 2 who were all competitive, sub-elite football players. No

restrictions were placed on therapies received at the time of data collection for this study. Participants in other groups self-classified as being involved in 'competitive' or 'recreational' physical activity/sport, with a wide inclusion of structured and unstructured activities.

Table 7.1. Source group study information.

	Group 1 Healthy controls	Group 2 FORCe	Group 3 PhysioFIRST	Group 4 HARP
Study type	Cross-sectional study	Observational cohort study	Randomised clinical trial	Observational cohort study
Sport and activity participation	No restriction on type or level of activity participation	Competitive, sub-elite football (soccer or Australian -Rules) players	No restriction on type or level of activity participation	No restriction on type or level of activity participation
Study specific outcome measures (Primary)	Mean daily step count.	MRI iHOT-33	iHOT-33	iHOT-33
RECRUITMENT				
Location **Method**	Victoria, Australia Posters, social media	Victoria and Queensland Australia Recruited from football clubs and league organisations	Victoria, Australia Posters, social media	Victoria, Queensland and Tasmania Australia Surgical lists, advertisements placed within the clinics
Participant recruitment for this study	August 2017 – January 2018	June 2018 to September 2019	February 2019 to December 2019	March 2017 to March 2018
ELIGIBILITY				
Inclusion	• No acute or chronic health problems limiting normal levels of activity • 18-50 years of age • Ability to understand written and spoken English	• >six-month history of hip-related pain. • Symptoms indicative of impingement. • Undertaking a minimum of two sessions of training/games per week • 18-50 years of age • Ability to understand written and spoken English	• Hip-related pain and signs and symptoms indicative of impingement • Alpha angle >60° • 18-50 years of age • Ability to understand written and spoken English	• Undergone hip arthroscopy for intra-articular pathology • 18-50 years of age • Ability to understand written and spoken English
Exclusion	• acute or chronic health conditions inhibiting normal levels of physical activity	• Planned lower-limb surgery in the following 2 years (e.g. arthroscopy); • Previous hip surgery; • Self-report of other diagnosed significant hip condition (e.g. trauma, rheumatoid arthritis, congenital dislocation of the hip, Perthes disease, subluxation, slipped upper femoral epiphysis, osteochondritis dissecans, fracture, septic arthritis, bursitis or tendinitis); • Contra-indications to magnetic resonance (MR) imaging; • Radiographic OA grade ≥2 on the Kellgren and Lawrence radiographic classification criteria; • Physical inability to weight-bear fully or undertake testing procedures.	• Physiotherapy treatment or hip joint injections in the three months prior to recruitment; • Previous hip or back surgery; planned lower limb surgery; • Other significant musculoskeletal or arthritis conditions; • Inability to perform testing procedures or commit to a six-month treatment programme; • Contraindications to X-ray (including pregnancy); • Pain not located in the hip or groin; • Pain <3/10 (0=no pain; 10=maximum pain); • Negative impingement tests.	• History of significant previous hip pathology (such as Perthes, slipped upper femoral epiphysis or avascular necrosis); • Previous hip injury such as acetabular fracture; • Physical inability to undertake testing procedures.

7.3.2.1 Group 1 - Healthy Controls

Participants were recruited from within the university and the wider community via posters, social media and word-of-mouth. Potential participants were eligible if they had no acute or chronic health conditions that inhibited their normal levels of physical activity. Details of this study group are defined in Study 3 (Chapter 6)[112].

7.3.2.2 Group 2 - FORCe (Femoroacetabular impingement and hip OsteoaRthritis Cohort)

FORCe is an observational cohort study. Soccer or Australian-Rules Football players with hip-related pain were recruited via social media advertisement campaigns, direct communication with football clubs and league organisations and mail-outs to participating organisations' membership lists. Full inclusion and exclusion criteria for the study have been published previously[44]. Potential participants were included if they had a greater than six-month history of hip-related pain, symptoms indicative of impingement and were undertaking a minimum of two sessions of training/games per week. Exclusion criteria included: planned lower-limb surgery in the following two years (e.g. arthroscopy); previous hip surgery; self-report of other diagnosed significant hip condition; contra-indications to magnetic resonance (MR) imaging; radiographic OA of grade ≥2 on the Kellgren and Lawrence radiographic classification criteria[120]; and physical inability to undertake testing procedures (Table 7.1). During June 2018 to September 2019, participants undertaking the study in Victoria were offered the opportunity to participate in the collection of physical activity data using a Fitbit™. The baseline data for this subgroup of participants are reported in this study.

7.3.2.3 Group 3 - PhysioFIRST (The Physiotherapy for Femoroacetabular Impingement Rehabilitation Study): (ACTRN12617001350314)

PhysioFIRST is a randomised clinical trial in which participants undergo physiotherapy intervention for a six-month period. Participants were recruited via advertisements (social media, blogs and print). Full inclusion and exclusion criteria for the study have been published previously[125]. Potential participants were included if they had hip-related pain and signs and symptoms indicative of impingement. Exclusion criteria included: physiotherapy treatment or hip joint injections; previous hip/back surgery or planned lower limb surgery; other significant musculoskeletal or arthritic conditions; inability to perform testing procedures or commit to a six-month treatment programme; contraindications to X-ray; Alpha angle <60°[4]; pain not located in the hip or groin; pain <3/10 on the Numerical Pain Scale; and negative impingement tests (Table 7.1). Baseline data for a subgroup of participants (recruited from February 2019 to December 2019) are reported in this study.

7.3.2.4 Group 4 - HARP (Hip ARthroscopy Prospective Study): (ClinicalTrials.gov Identifier: NCT02692807)

HARP is an observational cohort study. Participants who had undergone hip arthroscopy for intra-articular pathology (defined pragmatically by the treating surgeon, based on clinical and radiographic information) were recruited from three specialist Australian centres. Surgical lists were used to identify potential participants who were alerted to the study via email, telephone or advertisements placed within the clinics. Full inclusion and exclusion criteria for the study have been published previously[207]. Exclusion criteria included: a history of significant previous hip pathology; previous significant hip injury; and physical inability to undertake testing procedures (Table 7.1). The opportunity to undertake Fitbit™ data collection was offered to participants at a range of post-surgical time points, up to approximately one year. Post-arthroscopy data from this subgroup of participants (recruited from March 2017 to March 2018) are included in this study.

7.3.3 Outcomes

7.3.3.1 Primary outcome: Daily step count.

Daily step count was measured using commercial accelerometers. Participants in this study wore one of three Fitbit™ devices (Fitbit Inc., San Francisco, CA), the Fitbit Flex™ or Flex 2™ (Group 1,2 and 4) and the Surge™ (Group 3). All three devices are wrist-worn tri-axial accelerometers. Data were synced via the product interface (www.fitbit.com) providing outputs that include daily step count, activity minutes, estimation of calories consumed and distance related to step count. As the simplest algorithm, step count provides the most consistently reliable data (Study 2 and Study 3)[59, 61, 110, 112].

Mean daily step count was calculated for each participant. Data were categorised into the following groups, according to previous classification[242]:

- Sedentary (<5,000 steps per day)
- Low active (5,000 to 7,499 steps per day)
- Somewhat active (7,500 to 9,999 steps per day)
- Active (10,000 to 12,499 steps per day)
- Highly active (>12,500 steps per day)

The percentage of valid step count data returned for each group for the first episode of data collection (baseline for all groups) and repeat data collection episodes (Group 4) was calculated.

7.3.3.2 Other outcome measures.

To address study aim 2, the iHOT-33 was used to measure hip-related quality of life. The iHOT-33 was developed to measure health-related quality of life in young, active patients with hip disorders[168]. The measure contains 33 questions, covering four domains (symptoms and functional limitations; sports and recreational activities; job-related concerns; and social, emotional and lifestyle concerns) with numeric scores ranging from 0 (worst quality of life) to 100 (best quality of life). The tool has demonstrated adequate psychometric properties for young people following hip arthroscopy[123, 168] and those with hip-related pain[96, 105]. The predicted PASS score, indicating a magnitude of change associated with a satisfactory perceived improvement in the iHOT-33, has been reported as 58/100 points[161].

Self-reported demographic data (sex, age, height and body mass) were collected from participants at baseline. Body mass index (BMI, kg/m^2) was calculated from body mass and height.

7.3.4 Procedures/protocol.

Potential participants indicating interest in undertaking Fitbit™ data collection were supplied with additional information (supplementing the study-specific information sheet) and offered the opportunity to ask questions prior to screening and completing informed consent. Fitbit™ device set-up and data collection were supported by verbal and written instructions, with further support available from the research teams via telephone or email throughout data collection, including reminders of pending data collection and addressing any problems with the use of devices.

Initialising the Fitbit™ devices required demographic data (sex, date of birth, height and body mass) to be uploaded via the product's on-line interface. Each participant had an individual Fitbit™ account that was accessed remotely by specified members of the research team for the purpose of data extraction at pre-agreed time points. Participants were instructed to wear the devices on their non-dominant wrist with the band securely fitted. Participants were advised to remove devices when necessary to comply with sport-specific safety regulations, for water-based activities and overnight. For data to be successfully collected, participants needed to ensure the devices were charged and that the devices were synced to the interface to enable the output to be downloaded by the research teams.

All data collection periods were a minimum of two weeks duration, undertaken at baseline (Groups 1 to 3) and one year post-operatively (Group 4, one-year data) for comparative data (study aim 1). Post-arthroscopy patients (Group 4) entered this study at a range of post-surgical time points. Mean daily step count data were collected at point of entry into the study. All participants retained their devices. Participants less than six months post-surgery were offered the opportunity to provide data at more

than one time point, using the same device. Post-arthroscopy data were collated to provide an observation of mean daily step count in relation to a post-operative time point (study aim 3).

The iHOT-33 was administered to symptomatic participants via online data capture and storage platforms: FORCe and HARP via Checkware (CheckWare AS, Trondheim, Norway) and PhysioFIRST via Promptus (DS PRIMA, Melbourne, Australia).

7.3.5 Data management and analysis.

A single day's Fitbit™ data was deemed invalid (i.e. in circumstances where the device was not worn, or the battery was flat) when ≤ 1,500 steps were recorded[112, 241]. For each data collection period, a minimum of four valid days, including both weekend and weekdays, was required for the data to be included in the study[117, 238].

Data analyses were performed with SPSS (v25.0; IBM Corp) and Microsoft Excel, version 16. Statistical significance was assessed at $p \leq 0.05$.

For study aim 1, both mean daily step count and categorical mean daily step count data are presented descriptively. A multivariate regression analysis was applied to mean daily step count data, where step count was the dependent variable and group the independent variable. The model of best fit was initially determined, including the effects of covariates (age and sex) and interaction effects (group). Binomial logistic regression was performed to assess the influence of group, adjusted for age and sex, on whether mean daily step count was above or below 10,000 steps per day. This cut-off point was used to categorise active and highly active participants from their less-active counterparts[242].

For study aim 2, iHOT-33 scores are presented descriptively (total iHOT-33 score and sports and recreational activities subscale). Binomial logistic regression was used to assess the impact of group, adjusted for age and sex, on reaching the predicted PASS score for iHOT-33 (total), using a cut-off score of 58[161].

For study aim 3, mean daily step count data are presented descriptively. Data were grouped into periods of three to four months six to seven months and approximately one year to accommodate variation in data collection times. Participants appear only once in each group but were able to contribute to multiple groups.

For study aim 4, the proportion of valid step count data collection episodes were described for a single episode of data collection at baseline (across all groups) and repeated episodes of data collection (Group 4 only).

7.4 Results

7.4.1 Participant characteristics.

For study aims 1 and 2, cross-sectional data were analysed for 116 participants (Figure 7.2). This sample was comprised of 50% women. The sample population's mean age±standard deviation (SD) [range] was 35±9 [18 to 50] years and body mass index (BMI) was 25.5±4.5 [19 to 44] kg/m^2. Step count and iHOT-33 data were provided by 24 participants in Group 4 at approximately one year post-arthroscopy (58% women, 33% competitive; age 37±9 [22 to50] years and BMI 25±4 [19 to 35] kg/m^2) used for study aims 1 and 2. For study aim 3, 46 participants in Group 4 undertook one or more episodes of data collection at approximately three months, six months and one year post-arthroscopy. Group-specific characteristics are summarised in Table 7.2. A delay of six weeks was incurred by two participants in Group 4 when submitting step count data at one-year post-arthroscopy for hip-related pain. Where available data could be compared, no significant difference was evident between the characteristics of the participants and those from any of the groups who declined to participate (n=149) for sex, age, BMI and the iHOT-33 Sports and Recreational activities subscale (iHOT-33 SR) (Appendix 9a).

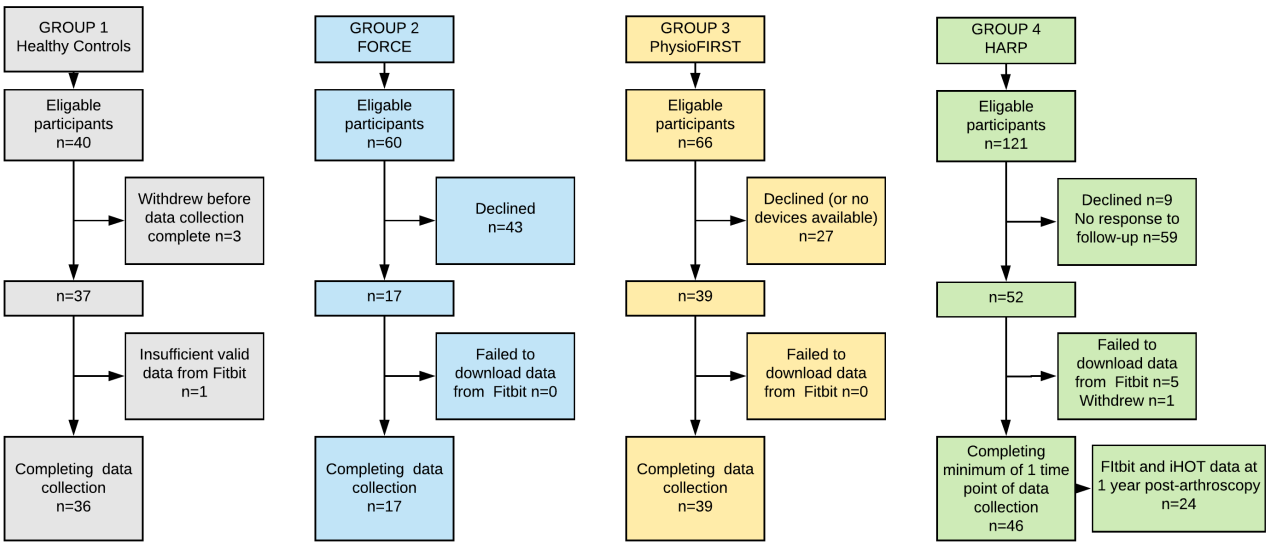

Figure 7.2. Flow of study participants in each study group.

Table 7.2. Demographic data, mean daily step count and iHOT-33 scores, by group.

	Group 1	Group 2	Group 3	Group 4
		Hip-related pain + competitive football	Hip-related pain + FAIS + physiotherapy	Post-hip arthroscopy
	Healthy Controls mean±SD [range]	**FORCe** mean±SD [range]	**PhysioFIRST** mean±SD [range]	**HARP** mean±SD [range]
n	36	17	39	46
Women, n(%)	16(44%)	3(18%)	25(64%)	29(63%)
Age, years	34±8 [20 to 50]	28±9 [18 to 49]	37±8 [19 to 49]	36±9 [21 to 50]
BMI, kg/m²	25±4 [19 to 37]	25±3 [20 to 31]	26±6 [20 to 44]	25±4 [17 to 35]
Participate in competitive sport (% of Group)	25%	100%	26%	37%
Steps/day	9,590±3,256 [2,795to 18,399]	10053±2769 [6,004 to 16,695]	10,393±3,848 [4,703 to 19,688]	‡‡9,568±2,850 [4,199 to 14,445]
†iHOT-33	ND	61±14 [31 to 89]	56±16 [27 to 93]	‡‡60±25 [13 to 95]
†iHOT-33 Sx	ND	63±16 [33 to 89]	63±16 [29 to 90]	‡‡65±25 [11 to 100]
†HOT-33 SR	ND	56±18 [20 to 88]	40±21 [14 to 96]	‡‡48±28 [0 to 94]
†iHOT-33 Job	ND	68±23 [30 to 100]	63±23 [13 to 100]	‡‡60±24 [0 to 90]
†iHOT Social	ND	59±18 [31 to 92]	50±22 [8 to 98]	‡‡53±31 [1 to 95]

Data are presented as mean±SD [range] unless otherwise stated. FORCe=Femoroacetabular impingement and hip OsteoaRthritis Cohort; PhysioFIRST=The physiotherapy for Femoroacetabular Impingement Rehabilitation Study; HARP=Hip ARthroscopy Prospective Study; n=number of participants; SD=standard deviation; BMI=Body mass index ; iHOT-33=International Hip Outcome Tool, total score; iHOT-33 Sx=Symptoms and functional limitations subscale;iHOT-33 SR=Sports and Recreational activities subscale; iHOT-33 Job=Job related concerns subscale; iHOT-33 Social=Social, emotional and lifestyle concerns subscale; †=0-100, 0=poor quality of life; ND=no data; ‡‡= data collected at 1 year post arthroscopy n=24.

7.4.2 Cross-sectional comparison of mean daily set count across groups (Study aim 1)

The distribution of mean daily step count data categorised by activity level is presented in Figure 7.3. Across all groups, 42% of participants were classed as highly active/active, 34% as active and 25% as low active or sedentary.

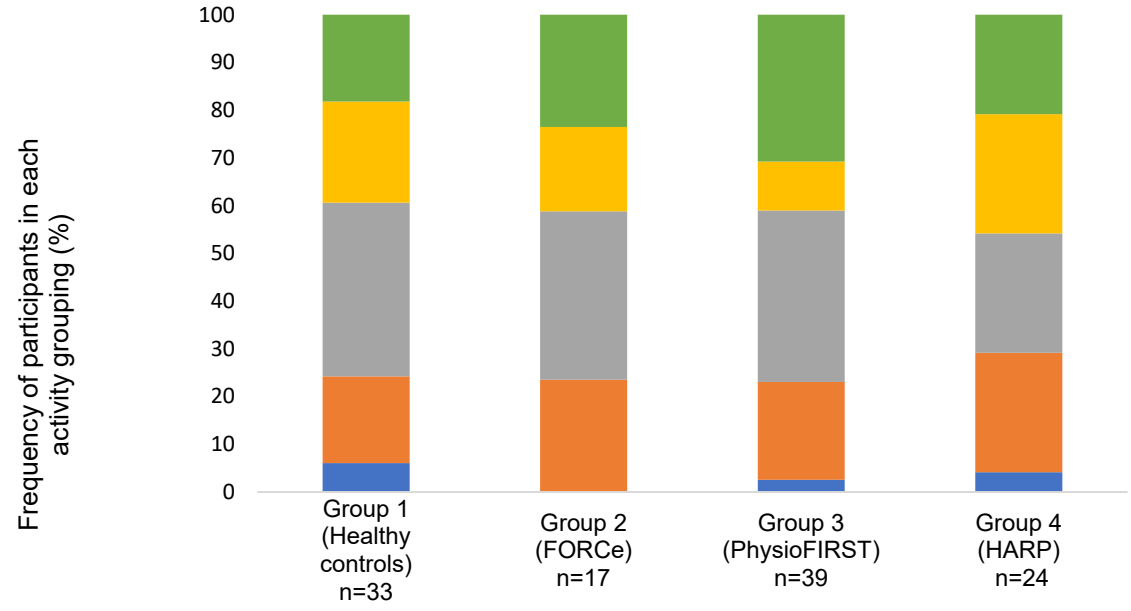

Figure 7.3. Frequency of mean daily step count categories within groups.

In order to determine which variables to include in the final regression model, the effects of group, age and sex were analysed (Appendix 9b). The final model included group, age and sex as covariates and accounted for 10% of the variance in step count (p=0.588, r^2=0.103), as shown in Table 7.3.

Table 7.3. Multivariate regression.

Dependent variable	Independent variables/covariates (included)	Beta co-efficient(p-value)	Adjusted model R^2
Step count	Group	86.518 (0.745)	0.105
	Sex	-1921.007 (0.002)	
	Age	105.507 (0.003)	

When assessing the impact of group, age and sex on mean daily step count (dichotomised as above or below 10,000 steps/day), the full regression model, containing all predictor variables, was not statistically significant χ^2=9.725, p=0.083. This result indicates there were no significant differences in step count between groups after adjustment for age and sex. The model explained between 8% (Cox and Snell R^2) or 11% (Nagelkerke R^2) of the variance in step count. Two of the independent variables made a statistically significant contribution to the categorisation of step count: age (p=0.003), where older participants were more likely to have a greater mean daily step count than younger participants, and sex (p=0.002), where men were more likely to have a greater mean daily step count than women, both regardless of group.

7.4.3 Hip-related quality of life across symptomatic groups (Study aim 2)

Descriptive statistics for iHOT-33 total and subscale scores for the symptomatic groups are presented in Table 7.2.

When assessing the impact of group, age and sex on reaching the predicted total iHOT-33 PASS score of 58, the full model, containing all predictors, was not statistically significant χ^2 =9.517, p=0.296. This result indicates there were no between-group differences in people achieving PASS scores for the total iHOT-33, after adjusting for age and sex. The model explained between 6% (Cox and Snell R^2) or 8% (Nagelkerke R^2) of the variance in the iHOT-33 PASS score.

7.4.4 Observation of mean daily step count at post-arthroscopy time points (Study aim 3)

Between three months to approximately one year post-arthroscopy, 82 episodes of data collection were available from 46 participants; 73 of these episodes were within the time frames identified in Table 7.4. The same individuals may appear in more than one timeframe group but are only represented once within each timeframe.

Table 7.4. Mean daily step count for participants in three timeframes from three months to approximately one year post-arthroscopy.

Time post-arthroscopy	3-4 months	6-7 months	1 year
Number of participants	19	19	35
Steps per day mean±SD	8129±2019	8560±2400	9169±3081
[range]	[4645 to 12257]	[4854 to 13679]	[2318 to 16781]
*Mean daily step count≥10,000	26%	16%	37%

SD=standard deviation; *Active/highly active.

7.4.5 Data return from commercial devices (Study aim 4)

As identified in Table 7.5, valid baseline data were successfully retrieved for ≥89% of participants.

Table 7.5. Retrieval of valid baseline data.

	Group 1 Healthy Controls	Group 2 FORCe	Group 3 PhysioFIRST	Group 4 HARP
Number of participants with Fitbit™ device	n=37	n=17	n=39	n=52
Successful set-up and download of data n(%)	36(97%)	17(100%)	39(100%)	46(89%)

FORCe=Femoroacetabular impingement and hip OsteoaRthritis Cohort; PhysioFIRST=The physiotherapy for Femoroacetabular Impingement Rehabilitation Study; HARP=Hip ARthroscopy Prospective Study

Issues with data collection and retrieval are presented in Table 7.6. At baseline, two participants failed to complete the procedures required to complete the set-up of devices and subsequently failed to respond to the research team. One participant reported being unable to manage the Fitbit™ application interface. One participant achieved set-up and download of data; however, insufficient days of valid data were returned to meet the criteria for inclusion, either due to a failure to charge or wear the device during the two weeks of data collection.

For participants in Group 4, valid data failed to be retrieved from approximately 24% of participants at repeat episodes of data collection undertaken subsequent to baseline (Table 7.6). Reasons for participant disengagement at these repeated data collection points were largely unidentified. Approximately 10% of devices needed to be replaced over the course of repeat data collection due to loss (4%) and breakage or technical failure (6%).

Table 7.6. Barriers to data collection and retrieval.

Reasons for lack of baseline data		
Number of eligible participants n=145	Failed to complete set-up of device	n=2
	Set-up completed but failed to download data	n=4 (including 1 participant who withdrew prior to data collection; 1 participant unable to manage Fitbit™ app interface; reason for disengagement unknown for 2 participants)
	Failed to wear/charge device for sufficient number of days	n=1
Repeat data collection (Group 4)		
6 months or less from baseline (Number of eligible participants n=28)	Reason for disengagement unknown (no response to follow-up)	n=5
	Unable to charge device while travelling	n=1
	Device broken (replacement required)	n=1
7 months to 1 year after baseline (Number of eligible participants n=26)	Reason for disengagement unknown (no response to follow-up)	n=5
	Failed to complete set-up of replacement device	n=1
Replacement devices (Initial number of devices distributed n=52)	Broken/technical failure	n=3
	Devices lost	n=2

7.5 Discussion

This study aimed to examine differences in mean daily step count data between four groups sited at different points on the spectrum of hip disease, from healthy controls to post-arthroscopy. The hypothesis that symptomatic participants would have a lower mean daily step count than their healthy peers was not supported. Group, across the three different hip-related pain groups, was not associated with mean daily step count when age and sex were accounted for. Being male was associated with a higher mean daily step count independent of group, aligning with previous population-based studies[39]. Participants of older age within the study also had an association with a higher mean daily step count, independent of group. The regression models only explained a small proportion of the variance in the outcome (around 10% for each model). This result reflects how physical activity, in this case operationalised by mean daily step count, is a complex construct probably impacted by many (including unmeasured) factors. Observations of step count between approximately three months, six months and one year following hip arthroscopy were similar, with participants at each time point having a mean daily step count commensurate with being 'somewhat active'[242].

Mean iHOT-33 scores varied by a maximum of five points between symptomatic groups ranging from 56, for participants with FAI syndrome seeking physiotherapy intervention for hip-related pain, to 61, for participants maintaining competitive sporting activity. All symptomatic groups had a mean iHOT-33 score close to the predicted PASS score of 58[161] which showed no association with age, sex or group. The mean iHOT-33 scores for all the hip-related pain groups were considerably lower than for previously reported healthy controls (97±5.9)[123], irrespective of their activity involvement and position

on the hip disease spectrum. While the lowest subscale scores for all symptomatic groups were seen in the sports and recreational activities subscale, indicating greater physical impairment during these activities, these patient-reported concerns are not reflected in objective measures of mean daily step count. This finding aligns with Kierkegaard et al. (2019)[131], who also describe discordance between physical activity measures acquired using accelerometry and perception of physical function identified using PROMs. The result adds weight to the supposition that perceived physical function and objectively measured physical activity are only partially related constructs[221] and that both subjective and objective measures are required to capture the nuances of physical activity.

The consistency in mean daily step count between the early post-arthroscopy period of three months to the one-year time point was surprising. When considered alongside previous studies where mean step count did not change from pre- to post-arthroscopy[131] and was commensurate with data from healthy controls both pre-surgery[87] and post-surgery[131], it appears that step count is a relatively consistent measure of daily activity. While the use of a wider range of accelerometer-derived metrics, such as velocity or intensity, may show more definitive changes, the findings of previous studies[107, 131] indicate similar consistency of other metrics, such as intensity, pre- to post-surgery, when considered at a group level. The lack of disparity in accelerometer-based measures also emphasises the need for researchers to include healthy controls in studies, as assumptions cannot be made that symptomatic individuals will present with objective deficits in comparison to their healthy counterparts.

Overall, compliance with retrieval of step count data using commercial trackers was high, particularly for cross-sectional data collection. Maintaining engagement with longitudinal data collection can be challenging, irrespective of the data collection tool used[29, 219]. Although device-specific difficulties were identified for a few participants as a barrier to repeated data collection, recognised retention strategies, such as clear scheduling, providing reminders and maintaining personalised communication with participants[1], allowed technical difficulties, or loss of devices, to be dealt with effectively by the research team prior to pending data collection. Where communication was lost, the reasons for disengagement could not be established. Disengagement with personal activity trackers, not associated with research, has been reported with approximately one-third of devices being abandoned within six to twelve months of use[89]. Researchers should be aware in planning future studies that extra input may be required to support participants to re-engage with devices during the follow-up period; however, this can be offset against the time that would be required to supply and retrieve research-grade devices during longitudinal studies. The dropout rates in the current study can be used to inform sample sizes for future studies using commercial accelerometers.

7.5.1 Clinical implications

This cross-sectional evaluation indicated that one-quarter of our participants had mean daily step counts of <7,500 steps per day, classing them as 'sedentary' or 'low activity' with respect to physical activity levels[138, 242]. When considering physical activity for health, this finding emphasises the need for clinicians to engage with the objective assessment of physical activity and, when necessary, include specific interventions to target physical activity goals to reach recommendations for health[74, 234]. However, clinicians should be aware of potential barriers to successful uptake, such as beliefs about the benefits and harms of physical activity, fear of exercising with pain or causing further damage, lack of access to facilities such as exercise equipment or personal activity trackers and extrinsic pressures such as work or childcare. Although, at a group level, no significant differences in mean daily step count were evident between healthy controls and symptomatic groups, evaluation of daily step count at an individual level may be useful in determining 'at risk' individuals and offer a resource for setting incremental, personalised goals and evaluating the effectiveness of interventions.

The sport and recreation subscale of the iHOT-33 asks questions of individuals with hip-related pain about the emotional impact of their ability to participate in sports and recreational activities[168]. Using this subscale, we identified a negative impact on perceived physical activity abilities in individuals with hip-related pain. While the use of objective goal-setting may help to alter perceptions of restricted activity, it is also vital for clinicians to monitor and, where necessary, address the psychological barriers of returning to physical activity following injury or surgery. Tools such as the 'Injury Psychological Readiness to Return to Sport (I-PRRS) Scale'[77] or the 'Hip-Return to Sport after Injury (HIP-RSI) scale' (Study 6, Chapter 9)[114, 266, 268] may promote understanding of the wider factors involved in making a successful transition back to confident engagement in sport and physical activity and be used to initiate clinical conversations in this area.

7.5.2 Limitations

Several limitations should be acknowledged in this study. Undertaking activity monitoring was not accepted by large numbers of the symptomatic study cohorts. Not wishing to undertake this additional burden likely reflects the data collection load already incumbent on participants and staff administering these studies. Operational issues, such as timely access to devices, particularly as devices were superseded, added to this shortfall. Although the large number of non-participants may have introduced some bias, the parity in age, sex, BMI and iHOT-33 SR scores between participants and non-participants implies adequate similarity in key characteristics between the two groups. Although group sizes for Group 3 and Group 4 were sufficient to meet the recommendations for an acceptable level of variation at group level for iHOT-33 scores (23 to 30 participants[96]) numbers in the FORCe cohort (Group

2) fell below this threshold. In the reporting of results, emphasis has been placed on presenting descriptive statistics rather than statistical comparisons, particularly where low numbers increased the risk of type II error. The findings of this study supplement previous study findings[87, 131] by presenting mean average daily step count across a spectrum of hip disease, but should be viewed with caution due to the potential biases introduced by low study numbers.

Participants in this study wore one of three Fitbit™ devices, the Fitbit Flex™ or Flex 2™ (Groups 1, 2 and 4) and the Surge™ (Group 3), which were not randomly assigned between groups. This distribution reflected the availability of models, as generations of devices evolved, and the 'real world' feasibility of using commercial devices for data collection. The risk of introducing systematic error was minimised by restricting comparisons to the most reliable metric of step count, as concluded from Studies 2 and 3[59, 110, 112]. While further measures of intensity and type of activity undertaken would add to the complex picture of physical activity, the simple representation of volume of ambulatory activity using step count is easy to understand, by patients and clinicians, and increasingly embedded in worldwide activity recommendations[138, 240, 244, 248]. Additionally, the step count findings concur with the more expansive physical activity metrics investigated by Kierkegaard et al. (2019)[131] for post-arthroscopy patients, indicating that the picture presented by the volume of ambulatory activity may be consistent with other objective measures of intensity. Although no clear criteria exist, the average time to return to sports activities following hip arthroscopy is seven months, ranging from three to 14 months[201]. Observing a time span of one year was considered to encompass the greatest potential changes in objective physical activity, although it should be noted that improvements in patient-reported outcomes for activities of daily living and sports-related activities may continue beyond two years[132].

The healthy control group used in this study were screened for musculoskeletal pain that impacted on their ability to undertake physical activity. The lack of specific screening for hip-related symptoms, however, presents a potential equivalence between this group (Group 1) and the FORCe (Group 2), who may also count their symptoms as not impeding their ability to undertake physical activity. Potential differences between these two groups would have been identified more clearly if the healthy controls had also completed the iHOT-33 as an additional measure. The finding that Group 2, consisting solely of competitive football players, had a similar mean daily step count to the mixed groups undertaking recreational and competitive activity in this study indicates that total daily ambulatory activity, measured with personal activity trackers, may be less influenced by formal than informal activities, although no formal assessment of device-use during training and match play was undertaken.

Using Fitbit™ devices to collect data presented some research challenges unique to the use of commercial, in comparison to research-grade, devices. From an operational perspective, supporting

participants to set up and successfully download devices increased the time demands on the research team. The onus of responsibility for wearing, charging and synchronising the devices lay with the participants, such that delays were incurred in data collection and downloads if participants were slow to respond to reminders from the research team. An assessment of hours of wear time per day is a frequently used validity criterion in studies utilising research-grade accelerometers[160] which is less easily reconciled in these commercial devices, particularly where third-party service providers (e.g. Fitabase.com) are not employed to access data. Using the devices over extended periods of time presented additional technical and operational challenges. Where devices were not used and charged between data collection periods, older devices frequently required a factory reset and updates to restore functionality. This could be time-consuming, not always successful and a source of frustration to both participants and the research team. Additionally, the research team found the battery life to be unstable in older models. Although the Fitbit™ devices are relatively discrete, easy to wear and therefore acceptable to participants, several were lost by participants during the study, requiring the additional cost of replacement. The ongoing development of devices also limited the technical support available as they became obsolete and limited the availability of specific models; however, the degree of equivalence between generations of a device has been previously established (Study 3, Chapter 6)[112]. Although not an issue specific to commercial devices, the wear position of accelerometers can influence step count[241] and wrist-worn commercial devices remain at the forefront of the market[8]. While this presents potential biases in relation to step count, limitations in accounting for different activity types, such as resistance exercises or cycling, are common to both grades of accelerometer[14]. It should also be noted that using any tracking device presents a potential bias in participant motivation, a phenomenon that was outside the scope of the current study.

7.6 Conclusions.

This study provides a proof of concept exploration of the use of commercial activity trackers to compare mean daily step count in groups of young to middle-aged adults who are asymptomatic and those with hip-related pain. Total daily volume of ambulatory activity, as defined by mean daily step count measured by wrist-worn commercial accelerometers, was consistent across the groups comprising healthy controls, individuals with hip-related pain, individuals with a diagnosis of FAI syndrome and post-arthroscopy patients. Patient-reported outcomes were also consistent between symptomatic groups but were considerably lower than previously reported normative data. There were no differences in relation to the numbers achieving a PASS for the iHOT-33 between the three symptomatic groups and mean daily step count was consistent across time points ranging up to one year post-arthroscopy. These findings support the premise that physical activity outcomes should encompass

both objective and subjective measures, as they provide a complementary perspective on this complex construct. While some limitations and challenges in the use of commercial devices were evident, this proof of concept study indicates these devices provided an acceptable return of step count data, particularly where this was sought at only one time point. The findings of this study set the scene for larger, future studies, where the identified barriers and challenges to collecting objective data on physical activity can be considered a priori and addressed.

PART C

READINESS TO RETURN TO PHYSICAL ACTIVITY AFTER HIP ARTHROSCOPY

CHAPTER 8 (STUDY 5): MISMATCH BETWEEN EXPECTATIONS AND PHYSICAL ACTIVITY OUTCOMES AT SIX MONTHS FOLLOWING HIP ARTHROSCOPY: A QUALITATIVE STUDY

Apparent inconsistencies are evident between objective physical activity data and patient-reported physical activity outcomes following hip-arthroscopy[131]. At one year post-hip arthroscopy, patient-reported outcomes suggest that the ability to function and participate in sport and physical activity remain restricted compared with healthy peers[231]. Study 1 (Chapter 3)[111] indicated that more than half of the reported Hip Outcome Score-Sport Scale outcome data failed to reach a score commensurate with a patient acceptable symptom state (PASS). Study 4 (Chapter 7) also identified that although step count was consistent between post-arthroscopy patients and healthy controls, this was not reflected in measures of perceived physical function. While both psychological and physical factors will play a role in a successful return to physical activity, our current understanding of these influences is limited. The aim of this chapter (Study 5) was to explore, using a qualitative approach, the factors influencing participation in physical activity for young to middle-aged adults at six months post-hip arthroscopy.

Jones, D. M., Kemp, J. L., Crossley, K. M., Hart, H. F. & Ackerman, I. N. (2020). Mismatch between expectations and physical activity outcomes at six months following hip-arthroscopy: A qualitative study. *Physical Therapy in Sport, 45*, 14-22. https://doi.org/10.1016/j.ptsp.2020.05.006

Appendix A & Appendix B referred to in the publication can be found in Appendix 10 of this thesis.

CHAPTER 9 (STUDY 6): PSYCHOMETRIC PROPERTIES OF THE HIP–RETURN TO SPORT AFTER INJURY SCALE (SHORT FORM) FOR EVALUATING PSYCHOLOGICAL READINESS TO RETURN TO SPORTS AFTER ARTHROSCOPIC HIP SURGERY

Psychological readiness is as an important factor in returning to sport and activity following injury and surgery[11, 12, 190]. Study 5 (Chapter 8) described a potential influence of psychological factors impacting upon physical activity participation following hip arthroscopy. Although general measures of psychological preparedness exist, no hip-specific tool is available for use with patients undergoing hip arthroscopy. The aim of this chapter (Study 6) was to determine the psychometric properties of a measure to assess psychological readiness to return to sport (the Hip-Return to Sport after Injury (short form)) in patients post-hip arthroscopy when returning to different levels of sport and physical activity.

This chapter contains the following publication in its entirety:

Jones, D. M., Webster, K. E., Crossley, K. M., Ackerman, I. N., Hart, H. F., Singh, P. J., … Kemp, J. L.(2020). Psychometric properties of the hip-return to sport after injury scale (short form): Evaluating psychological readiness to return to sport following hip arthroscopy. *American Journal of Sports Medicine, 48*(2), 376-384. https://doi.org/10.1177/0363546519888644

Psychometric Properties of the Hip–Return to Sport After Injury Scale (Short Form) for Evaluating Psychological Readiness to Return to Sports After Arthroscopic Hip Surgery

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Investigation performed at La Trobe University, Melbourne, Australia

Background: Successful return to sports activity after surgery requires both physical and psychological readiness. The Hip–Return to Sport After Injury (Short Form) has been developed to assess psychological readiness to return to sports after hip injury and hip surgery, including hip arthroscopy.

Purpose: To evaluate the reliability, validity, responsiveness, and interpretability of the scale for a cohort of patients after hip arthroscopy with a range of sports participation levels.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: Invitations to participate were sent to 145 patients from 3 specialist surgeons. The study included 77 participants 1 to 24 months after hip arthroscopy (mean ± SD age, 35 ± 9 years; 62% women) and 33 healthy age-matched controls (age, 37 ± 7 years; 52% women). The scale was administered electronically on 3 occasions to patients: baseline (≥1 month postarthroscopy), 1 week later, and 6 months later. In addition to the scale, participants were asked about sports participation status and their global rating of postsurgical change. The scale was administered to healthy controls on 1 occasion. The minimal detectable difference, discriminant validity, floor and ceiling effects, responsiveness, and interpretability (minimally important change) were determined for the scale.

Results: Among the postarthroscopy group, excellent test-retest reliability was found (intraclass correlation coefficient = 0.869; 95% CI, 0.756-0.932) with a minimal detectable difference of 26 points out of 100 at the individual level and 4 points out of 100 at the group level. At baseline discriminant validity was evident between those who had returned to sports (median = 69, n = 35) and those who had not returned to sports (median = 30, n = 42; Mann-Whitney *U* score = 232.5, $z = -5.141$, $P < .001$) and between the returned-to-sports postarthroscopy group and healthy controls (median = 96, n = 33; Mann-Whitney *U* score = 165.500, $z = 5.666$, $P < .001$). No floor or ceiling effects were evident. Responsiveness was demonstrated for the scale in relation to sports status. With sports status as an anchor, a minimally important change of 26 points was identified.

Conclusion: Assessment of the Hip–Return to Sport After Injury (Short Form) supports its use as a reliable and valid measure of psychological readiness to return to sports in patients after hip arthroscopy.

Keywords: hip arthroscopy; psychological readiness; return to sports

For the young adult population undergoing hip arthroscopy, regaining the ability to participate in sports and activity is important for social and health-related perspectives. This desire to return to activity was highlighted by Mannion et al,[16] who assessed the expectations of a cohort of 86 people undergoing arthroscopic or mini-open surgery for femoroacetabular impingement. More than 90% expected surgery to confer an improvement in their ability to undertake sports, an expectation that remained unfulfilled for 60% of the cohort at a 12-month follow-up.

Guiding a successful return to sports and activity requires clinicians to assess patients' physical and psychological milestones throughout rehabilitation, with readiness in both aspects being vital to a satisfactory outcome.[23] In a 2016 consensus statement on return to sports, Ardern et al[1] identified the need for tools to assess readiness for return to sports to guide the decision-making

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process. The traditional bias has been toward physical testing rather than psychological.

The importance of psychological readiness in a successful return to activity has been highlighted in recovery from anterior cruciate ligament (ACL) injury. Psychological readiness has been established as an entity discrete from tests of physical function[39] and as the factor most strongly associated with return to preinjury activity.[2] More recently, Webster et al[38] also showed psychological readiness to be the factor most strongly associated with return to preinjury performance. It is important to determine if similar issues exist in patients undergoing hip arthroscopy, a commonly performed procedure for young to middle-aged adults with hip pathologies.[19,22] The Hip–Return to Sport After Injury (Short Form), or HIP-RSI(sf), is an adaptation of the Anterior Cruciate Ligament–Return to Sport After Injury (Short Form), or ACL-RSI(sf).[36] The ACL-RSI(sf) consists of 6 questions and is established as an adequate measure of psychological readiness to return to sports after ACL injury or surgery.[17,36] Questions in the HIP-RSI(sf) are less knee specific than those in the 12-item long form,[37] with the potential to be adapted to other injuries and diseases.[36] The HIP-RSI(sf) has yet to be used in relation to hip arthroscopy or hip injury, and its psychometric properties are unknown. Therefore, this study aimed to determine the psychometric properties of the HIP-RSI(sf) in patients after hip arthroscopy who are returning to different levels of sports. We hypothesized that the HIP-RSI(sf) would demonstrate adequate reliability, validity, responsiveness, and interpretability to determine the psychological readiness of patients after hip arthroscopy to return to physical activity (including sports).

METHODS

Study Design

This psychometric evaluation formed part of a prospective longitudinal cohort study undertaken between October 2017 and November 2018. Ethics approval for the study was obtained from the La Trobe University Human Ethics Committee (approval HEC16-137). All participants provided informed consent.

Participants and Recruitment

Patients (age, 18-50 years) who had undergone hip arthroscopy surgery in the previous 24 months and were at least 1 month postsurgery were recruited from 3 specialist Australian centers (3 surgeons in total, 1 per center), based in Victoria, Queensland, and Tasmania. Participants were provided with written information on the study and offered the opportunity to ask further questions. Participants were excluded from the study if they had a history of significant hip pathology such as Perthes disease, slipped capital femoral epiphysis, avascular necrosis, or significant trauma such as fracture or dislocation (based on medical history, which may or may not have included imaging taken as part of routine clinical care). No restrictions were placed on pre- or postoperative sports participation type or level.

Healthy control participants aged 18 to 50 years were recruited from university staff, students, and the wider metropolitan area via social media. Healthy control participants were excluded if they had undergone hip surgery or experienced any hip pain or dysfunction related to trauma or pathology. Similar to the hip arthroscopy group, in the healthy control group, no restrictions were placed on type or level of sports participation. All participants were required to be sufficiently fluent in written English to provide informed consent.

Hip–Return to Sport After Injury (Short Form)

The HIP-RSI(sf) is an adaptation of the ACL-RSI(sf),[36] whereby the word *knee* is replaced with *hip* for 4 of the 6 questions that cover 3 key constructs (emotions, confidence in performance, and risk appraisal) (Table 1). Each item consists of a scale graded 0 to 100, with the descriptors *extremely* and *not at all* representing opposite ends of the continuum. Individual item scores are summed and averaged to provide a single score for the scale. Higher scores indicate greater psychological readiness to return to sports.

Procedures

The HIP-RSI(sf) (Appendix 1, available in the online version of article) was administered with the REDCap electronic data capture system.[10] An email containing a link to the items was sent to participants. If no response was received in 5 days, the email was resent. Each email was prefaced by a message inviting participants to complete questions about their return to sporting activity after their hip arthroscopy. To ensure that participants interpreted "sport" in a wider community context, inclusive of noncompetitive sporting activity,[9] the invitation to complete the

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TABLE 1
Hip–Return to Sport After Injury (Short Form)

Construct	Questions
Emotions	Are you nervous about playing your sport?
	Do you find it frustrating to have to consider your hip with respect to your sport?
	Are you fearful of reinjuring your hip by playing your sport?
Confidence in performance	Are you confident that you could play your sport without concern for your hip?
	Are you confident that you can perform at your previous level of sport participation?
Risk appraisal	Do you think you are likely to reinjure your hip by participating in your sport?

questionnaire included the following: "You do not need to consider yourself a competitive sportsperson to complete the questions. Your answers may relate to your preferred physical activity." The scale was administered electronically on 3 occasions to patients postarthroscopy: baseline administration (administered at 1 time point when the participants were at least 1 month and ≤24 months postsurgery), administration 1 week later (to determine test-retest reliability), and a final administration 6 months after baseline administration (to determine responsiveness of the scale). The scale was administered once to healthy controls to determine discriminant validity.

In addition to the 6 HIP-RSI(sf) questions, participants were asked to report their current sports status (returned to sports or not returned to sports). Perceived change after surgery was assessed by asking participants to consider their hip condition "now, compared with before surgery" on an 11-point Global Rating of Change (GRC) scale ranging from 1 (a very great deal better) to 11 (a very great deal worse) (Appendix 2, available online). At baseline, participants were asked if they had received clearance from their orthopaedic consultant to return to sports.

To determine test-retest reliability, invitations to repeat the HIP-RSI(sf) were sent to participants who returned their initial responses within 1 week. The test-retest administration occurred 1 week after response to the initial questionnaire was received. This was considered to be an appropriate period for minimizing potential changes in activity participation and potential memory effects.

To determine the responsiveness of the scale, the HIP-RSI(sf) was administered 6 months later to all participants who had responded at baseline. At this administration, participants were also asked to identify which of the following statements most aptly described their current status:

- "Changed type of sport or level of participation, unrelated to hip and groin pain"
- "Not participating in any sport due to hip and groin pain"
- "Participating in a different sport due to hip and groin pain"
- "Participating in the same sport, at a lower level due to hip and groin pain"
- "Participating in the same sport, at the same level as before the onset of hip and groin pain"

The HIP-RSI(sf) was administered to a comparison group of healthy controls at a single time point only.

Psychometric Properties and Statistical Analysis

Data analysis was performed with SPSS (v 25.0; IBM Corp). At baseline, independent-sample *t* tests were used to compare differences between responders and nonresponders for age and time since surgery for the post–hip arthroscopy group. A P value ≤.05 (2-tailed) indicated a significant difference in mean scores.

Within the reporting of results, tables are used to collate descriptive statistics, and levels of significance are reported within the text preceding the tables.

Reliability. Test-retest reliability was calculated with a paired *t* test to compare mean scores. Effect size, calculated as mean change in score divided by the standard deviation of baseline scores,[12] was reported with criteria as described by Cohen[6]: 0.1 = small, 0.3 = medium, and 0.5 = large effect. Intraclass correlation coefficients (ICCs) were also calculated (model 2, 1), as were 95% CIs. Reliability was judged on the following guidelines for ICC ranges: <0.40, poor; 0.40 to 0.59, fair; 0.60 to 0.74 good; and 0.75 to 1.00, excellent.[5] Internal consistency was assessed at baseline with Cronbach alpha and considered to be adequate if >0.70.[30]

The minimal detectable difference (MDD), defining the smallest score that passes the threshold of error for the scale, was calculated with the standard error of measurement (SEM) according to the formula $\text{SEM} = \text{SD} \times \sqrt{1 - \text{ICC}}$,[15,24] with SD based on scores from all participants and as assessed from the baseline responses to the HIP-RSI(sf). Based on the 95% CIs, the following formulae were used[4,7]:

$$\text{Individual} - \text{level MDD} = 1.96 \times \text{SEM} \times \sqrt{2}$$

$$\text{Group} - \text{level MDD} = \left(1.96 \times \text{SEM} \times \sqrt{2}\right)/\sqrt{\text{n}}$$

Validity. At baseline, discriminant validity was evaluated by comparing participants grouped according to their self-reported return-to-sports status (returned to sports or not). It was hypothesized that if psychological factors affected return to sports after hip arthroscopy, participants who had returned to sports would score more highly on the HIP-RSI(sf) than those who had not returned to sports and that the magnitude of this difference would be greater than the MDD. For participants who identified consultant clearance to return to sports at baseline, the HIP-RSI(sf) scores were compared between those who reported that they had returned to sports and those who had not. Additionally, the HIP-RSI(sf) was administered once to healthy controls to further evaluate discriminant validity between known groups. Between-group scores were evaluated with a Mann-Whitney *U* test (significance level, $P \geq .05$).

Further exploration of the ability of the scale to discriminate among individuals at different levels of psychological readiness was undertaken at the 6-month data collection

point by comparing HIP-RSI(sf) scores with the 5 potential return-to-sports "current status" statements selected by participants at this time point. Groups were compared with 1-way nonparametric analysis of variance (ANOVA). Bonferroni adjustments were applied for comparisons of >2 groups in post hoc tests.

Construct validity of the HIP-RSI(sf) was evaluated by examining the relationship between HIP-RSI(sf) scores and responses to the GRC at baseline. To facilitate comparison, GRC scores were grouped to form the following categorical variables: better (GRC items 1-4), small change or no change (GRC items 5-7), and worse (GRC items 8-11). It was hypothesized that higher HIP-RSI(sf) scores (indicating greater psychological readiness to return to sports) would be associated with lower GRC scores (indicating feeling better). Differences in mean HIP-RSI(sf) scores across the GRC categories were assessed with a 1-way nonparametric ANOVA.

Floor and ceiling effects in the HIP-RSI(sf) were investigated. Floor effects were deemed to be present if >15% of participants demonstrated the lowest possible score, and ceiling effects were present if >15% scored the highest possible score.[13,30,34]

Responsiveness. Responsiveness was determined with an anchor-based approach[24] including all participants who returned questionnaires at 6 months. The relationship between the change in HIP-RSI(sf) scores over 6 months and GRC was explored with the Pearson correlation coefficient (r), and the relationship to returned/not returned to sports, with a point-biserial correlation (r_{pb}). We hypothesized a priori that a correlation of r (r_{pb}) > 0.400 ($P < .05$)[32] would exist between the change in HIP-RSI(sf) score and GRC score or return-to-sports status. Additionally, effect size for change over the 6-month period was calculated.

Interpretability. Minimal important change (MIC) reflects the smallest amount of change in a score that is meaningful to a patient.[18] The MIC was determined with the 75th percentile method described by Tubach et al,[35] where the MIC (follow-up score – baseline score) was determined for the lowest 75% of participants who record a change of "better" (GRC scores 1-4). The process was repeated with sports status as an anchor (returned to sports or not). To provide a comparison, MIC was also calculated with half the standard deviation at baseline, consistent with the methods used by Norman et al[20] (0.5 × SD).

RESULTS

Baseline Participant Characteristics

Invites to participate were sent to 145 patients after hip arthroscopy, with the following proportions from each specialist center: Victoria, 56%; Tasmania, 33%; and Queensland, 11%. The flow of participants through this study is summarized in Figure 1. No significant difference was found in age (P = .076) and time since surgery (P = .426) between responders (n = 77) and nonresponders, although a significantly higher percentage of nonresponders were men (n = 40, P = .017). Invitations to complete the HIP-RSI(sf) were also sent to 90 healthy controls. Responses were returned by 37% (n = 33). No significant differences were apparent between healthy controls and responders for age (P = .711) and sex (P = .304). Descriptive participant characteristics are presented in Table 2. At the 6-month administration of the HIP-RSI(sf), participants were between 7 and 30 months postarthroscopy.

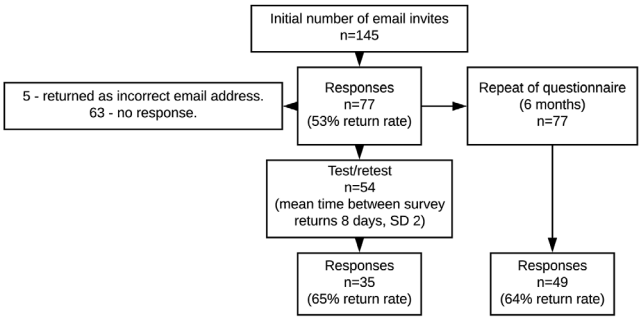

Figure 1. Flow of participants through the study.

Of the 77 participants who responded to the invitation, 70 (91%) in the study group provided a description of their involvement in sporting activity. Of these 70 participants, 54% (n = 38) described their involvement as recreational, 40% (n = 28) as competitive, and 4% (n = 3) as elite. One participant was self-described as sedentary. Within the healthy control group, 85% (n = 28) of participants described their involvement as recreational, 12% (n = 4) as competitive, and 3% (n = 1) as elite.

Reliability

Descriptive data are presented in Table 3 for test-retest reliability. There was no significant difference between the first and second completion of the questionnaire (P = .843, effect size = 0.02). Excellent test-retest reliability was found (ICC = 0.869; 95% CI, 0.756-0.932; $P \leq .001$). The scale had a high internal consistency with a Cronbach alpha of 0.92. Interitem correlations were suggestive of a strong relationship among items (mean = 0.64, minimum = 0.39, maximum = 0.81).

The score for the SEM was 9.37, and the score for the MDD (scale, 0-100) was 26 at the individual level and 4 at the group level.

Validity

Discriminant Validity. Validity was assessed by comparing baseline scores between respondents who had returned to sports (n = 35) and those who had not (n = 42) (Table 3).

Thirty-five participants identified themselves as having returned to sports (20 women, 15 men; mean ± SD [range]: age, 35 ± 9 years [20-50 years]; time since arthroscopy, 10 ± 6 months [2-24 months]) and 42 as having not returned to sports (28 women, 14 men; age, 36 ± 8 years [22-50 years]; time since arthroscopy, 7 ± 5 months [1-22 months]). A Mann-Whitney U test identified a significantly

TABLE 2
Participant Characteristics

		Participants, n (%)		Age, y			Postsurgery, mo[a]		
Administration	n	Women	Men	Mean	SD	Range	Mean	SD	Range
Baseline									
Whole cohort	145	76 (52)	69 (48)	35	9	19-50	9	5	1-24
Nonresponders	68	28 (41)	40 (59)	34	9	19-50	9	5	1-20
Responders	77	48 (62)	29 (38)	36	8	20-50	8	6	1-24
Test/retest: responders	35	19 (54)	16 (46)	35	10	21-50	8	6	1-24
6 mo: responders	49	32 (65)	17 (35)	36	8	21-50	14	5	7-30
Healthy controls: responders	33	17 (52)	16 (48)	37	7	26-50			

[a]Number of months between surgery and administration of the questionnaire.

TABLE 3
Descriptive Statistics, Test-Retest Reliability, and Discriminant Validity[a]

	HIP-RSI(sf) Score			
	Mean	SD	Maximum	Minimum
Test-retest reliability (n = 35)				
Completion 1	43	26	97	0
Completion 2	44	27	92	0
Discriminant validity (n = 77)				
Returned to sports (n = 35)	62	21	97	22
Not returned to sports (n = 42)	32	22	80	0
Healthy controls (n = 33)	90	14	100	43

[a]HIP-RSI(sf), Hip–Return to Sport Index (Short Form).

higher HIP-RSI(sf) score for those who had returned to sports (median = 69, n = 35) than those who had not returned to sports (median = 30, n = 42; Mann-Whitney U score = 232.5, z = –5.141, $P < .001$). The difference in the mean score (30) was greater than the calculated MDD (26 at individual level and 4 at group level).

Comparison of the 5 current status statements (Figure 2) at the 6-month administration of the HIP-RSI(sf) showed a significantly higher score associated with participants returning to the same sport at the same level preoperatively (median = 80, n = 14) as compared with "not participating in any sport due to hip and groin pain" (median = 17, n = 6; P = .002) and "participating in a different sport due to hip and groin pain" (median = 39, n = 12; P = .003).

At baseline administration, the number of participants reporting consultant clearance to return to sports was 47, of whom 14 (36%) had not yet returned to sports. A Mann-Whitney U test identified a significantly greater psychological readiness to return to sports for those who reported being given clearance and had returned to sports (median = 69, n = 33) than those given clearance who had not returned to sports (median = 33, n = 14; $P < .001$).

Participants postarthroscopy who reported having returned to sports at baseline (median = 69, n = 35) demonstrated significantly lower psychological readiness than healthy controls (median = 96, n = 33; $P < .001$).

Construct Validity. At baseline administration, a 1-way nonparametric ANOVA evaluation of HIP-RSI(sf) in relation to categorized GRC scores identified a statistically significant difference across 3 groups: "better," "small change or no change," and "worse" since surgery ($P < .001$) (Figure 3). Post hoc tests showed significantly higher HIP-RSI(sf) scores associated with participants who classed themselves as better since surgery as compared with those identifying as worse ($P < .001$) and in relation to small/no change (P = .010). The median number of months (interquartile range) after surgery at this time of baseline administration for participants classified as better, small or no change, and worse was 6 (4.8-12), 6 (5-12.5), and 4 (4-10.8), respectively.

No floor or ceiling effect was evident for the HIP-RSI(sf), with only 1% of participants achieving the lowest possible score and no participants achieving the highest possible score at baseline or 6 months.

Responsiveness

HIP-RSI(sf) change scores from baseline to 6 months were not correlated with the GRC (r = 0.214, P = .144). Correlation ($r > 0.400$) was found in relation to dichotomous sports status (returned/not returned) (r_{pb} = .550, $P < .001$). A small effect size (–0.134) was evident.[6]

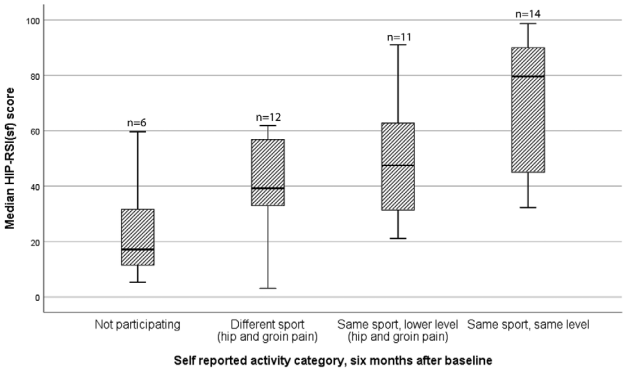

Figure 2. Box plot of HIP-RSI(sf) scores for self-reported activity categories at 6-month administration, showing median score and maximum and minimum values for each group. ''Changed type of sport or level of participation, unrelated to hip and groin pain'' is omitted from this figure (n = 2). HIP-RSI(sf), Hip–Return to Sport Index (Short Form).

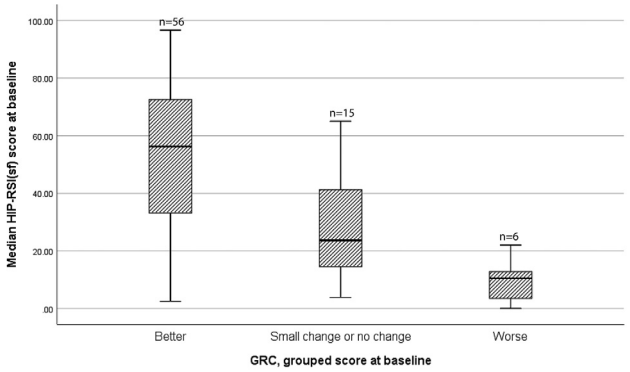

Figure 3. Box plot of HIP-RSI(sf) scores associated with grouped GRC data, showing median score and maximum and minimum values for each group. GRC items: 1-4 = better, 5-7 = small change or no change, 8-11 = worse. GRC, Global Rating of Change; HIP-RSI(sf), Hip–Return to Sport Index (Short Form).

Interpretability

A score of 18 (on a scale of 100) was calculated as the MIC with the GRC as an anchor. With sports status as the anchor (returned to sports/not), a score of 26 was calculated. Comparatively, the MIC was 13 when calculated with the method of Norman et al.[20]

DISCUSSION

This study evaluated the key measurement properties of an index to assess psychological readiness for return to sporting activity after hip arthroscopy. For a cohort of postoperative patients aged 18 to 50 years, results indicated that the HIP-RSI(sf) is a valid and reliable scale to assess psychological readiness for those undertaking recreational and competitive sports activity.

Reliability

Consistency of HIP-RSI(sf) scores was demonstrated, implying that the scale can be used to track the progress of individuals and groups of patients after hip arthroscopy.[40] The demonstrated Cronbach alpha of 0.92 replicates previous findings in the development of the ACL-RSI(sf),[36] in which retention of all 6 items was deemed to be appropriate to represent the 3 domains of emotion, confidence, and risk appraisal when returning to sports activity.[37] The error, as identified in this study, that should be considered when interpreting the scale on a single occasion for the population studied is approximately 10% (SEM = 9). When assessing change scores, clinicians are advised to consider changes of approximately 25% for individuals to be confident of real change in psychological readiness that exceeds random error. Although this figure is similar to the MDD at the individual level, as reported for other hip-related patient-reported outcome measures, such as the Physical Activity and Quality of Life subscales of the Copenhagen Hip and Groin Outcome Score (18% and 19%, respectively),[13] it may reflect the heterogeneity of the cohort observed in the current study regarding the mixed level of sports participation.

Validity

The ability of the score to differentiate between participants who had and had not returned to sports was demonstrated for the scale and the ability to discriminate between patients who have returned to sports postarthroscopy and healthy controls. The COSMIN initiative (Consensus-Based Standards for the Selection of Health Measurement Instruments)[25] counsels against dependence on statistical significance when making comparisons between groups. Decisions are more aptly based on the context, direction, and magnitude of the difference. In our study, statistical significance was demonstrated, and the scores for those who had returned to sports were higher than those who had not returned to sports, indicative of greater psychological readiness. The magnitude of the difference between mean scores was greater than the MDD, and this relationship is more profound at group level than at the individual level. Low scores that were identified for those participants who had not returned to sports but who reported clearance from their orthopaedic surgeon imply that psychological factors are potentially influential once physical barriers are more subordinate in the decision-making process. The judgments and ethical obligations of all health care professionals supporting patients to return to sports and physical activity after hip arthroscopy are complex.[3] The use of scales such as the HIP-RSI(sf) should be encouraged in the decision-making process to assist in determining psychological readiness.[28] In

relation to ongoing rehabilitation, our data, although restricted by low subgroup numbers, suggest that the scale can discriminate among individuals at different points of psychological readiness to return to sports based on the patient-selected categories identified at 6 months. Lower HIP-RSI(sf) scores seen in participants who had returned to sports as compared with healthy controls are indicative of the lack of clarity offered by assessment of dichotomous sports status as an outcome, with returning to sports not necessarily being associated with full psychological recovery. In addition, we must be aware of the possible differences between elite and recreational athletes in terms of their desired level of return to sports, as well as their psychological readiness. The lack of floor and ceiling effects for the scale is indicative of the ability of the HIP-RSI(sf) to detect improvement or deterioration in a group with varying levels of involvement with sports.

The directional trend of group GRC scores and HIP-RSI(sf) scores was positively linked, with improvements in psychological readiness being related to a more positive GRC score. However, the wide spread of HIP-RSI(sf) scores associated with the "better" GRC grouping indicates that psychological readiness should be specifically assessed by the HIP-RSI(sf) and not assumed to equate to a positive GRC score.

Responsiveness

The ability of the HIP-RSI(sf) to measure change over time was also assessed. The scale was shown to be responsive to change in sports status over time, with the correlation between dichotomous return-to-sports status and the scale meeting the hypothesis ($r > 0.400$). The lack of correlation with the GRC score most likely reflects the limited identity between the scores, as outlined earlier. The relevance of GRC scores to functional outcome scores has been questioned,[29] with the dissonance between the scales potentially being too great in relation to the constructs being measured and with correlation decreasing still further over time as recall bias plays a more dominant role. However, when the correlation between progression in physical ability (hop test) and outcome scores after ACL surgery was assessed, a better correlation was found with the GRC score than with the Lower Limb Functional Score, indicating that the applicability of anchor scores may be a more complex issue.[27]

A small effect size was also evident, indicating that the HIP-RSI(sf) was able to detect change between baseline and 6 month administration; this was similar to the reported effect size for the Physical Activity subscale on the Copenhagen Hip and Groin Outcome Score.[13] The mixed nature of the cohort, in relation to the postoperative stage, is likely to have influenced the profile of change scores.

Interpretability

The ideal process of determining the minimal change that could be interpreted as important to the individual is open to some debate.[13,31,33] For this study, 2 methods of calculation were applied. With an anchor-based approach, an MIC of 18 was identified with the GRC as the anchor, as opposed to 26 with the use of returned to sports/not as the anchor. Validity comparisons between these anchor scales would imply that returning to sports has greater relevance as an anchor. This higher score is also closer to the MDD at the individual level, which could be argued to identify the score as being more appropriate.[33] The anchor-based approach provides a more conservative option. By utilizing a distribution-based method, the MIC was lower (13) and less than the MDD for individual-level responses. The dilemma of interpreting MIC scores that are lower than individual-level MDD scores is a common theme identified in the psychometric analysis of patient-recorded outcome measures for arthroscopic hip surgery.[13,33] Group-level interpretations of change scores can be made with greater confidence.

Clinical Implications

Successful return to sports after injury or surgery requires psychological and physical readiness. To date, there has not been an accessible and easily administered scale for practitioners to assess psychological readiness alongside more frequently measured physical milestones. This study showed that the HIP-RSI(sf) could be used by clinicians treating patients after hip arthroscopy, alongside measures of physical function, to determine whether their psychological status is likely to be sufficient for a successful return to sports. Given the low rate of patients returning to the same level of sports with optimum performance or successfully returning to physical activity,[11,33] it is vital that clinicians have appropriate tools to monitor and support this transition.

Strengths and Limitations

Substantiating validity of an outcome measure should be viewed as an ongoing process supported by multiple research efforts.[24] This preliminary assessment of the HIP-RSI(sf) has begun to establish psychometric properties of the scale; however, a number of limitations should be acknowledged.

The cohort used for this study was a representative sample of patients after hip arthroscopy. This has several implications. The range of sports activity participation and postoperative recovery within the cohort was beneficial to include a wide variance of psychological readiness to returning to sporting activity. While the factors affecting successful return to sporting activity will be multifactorial, irrespective of sporting level, the number of elite athletes in this study was limited. Psychological influences for elite athletes are likely to be different from those for recreational athletes and those who do not class themselves as athletes but are returning to their preferred physical activity. Further validation of the HIP-RSI(sf) should be undertaken in the specific context of elite sports. Additionally, De Vet et al[7] identified that the MIC is influenced by baseline scores. The range of postoperative time points included

at baseline enabled us to capture a wide spectrum of progression through rehabilitation; however, this may have influenced baseline scores. Although the average time of return to play is 7 months,[21] the range of recommendations is wide[8] and will be influenced by the requirements of the individual. Additionally, the progress of psychological readiness to return to activity is not clear-cut, with some authors identifying a counterintuitive increase in confidence soon after injury.[26] Patients at postoperative 24 months were included, as recent research has identified that a patient's ability to function and participate in sports and physical activity is still markedly reduced at 1 year after hip arthroscopy[33] and that improvement continues over a period of 2 years.[14] Further research on homogeneous cohorts, such as patients at specific postoperative time points, is recommended alongside the evaluation of psychometric properties under different conditions, such as nonsurgical rehabilitation. For the purposes of this study, the assumption of content validity was based on the robust theoretical underpinnings of the Anterior Cruciate Ligament–Return to Sport After Injury and the reduction of this scale to the short form, ACL-RSI(sf),[36] in which knee-specific references were removed, facilitating translation of the scale to other areas. Extending future studies to encompass an assessment of hip-specific content validity would provide a more comprehensive analysis of this property. The potential factors underpinning the higher female response rate in the current study are unknown. Future participant involvement in the assessment of content validity would serve to identify possible sex biases within the questions.

Although the age and sex of the control and study groups were comparable, the control group included a higher proportion of recreational athletes. Future studies assessing the psychometric properties of the scale could focus on high-level athletes and should take this into consideration to include healthy controls with the same activity profile. As highlighted here, the psychological profiles of those returning to high-level sports or lower-level physical activity are unlikely to follow the same trajectory. While this study placed no restrictions on the physical activity of participants, it should be noted that the participation status was unknown for 9% of study group respondents, introducing a potential source of bias. The assessment of discriminant validity at baseline and 6 months included only participants with a reported activity status. All participants in the control group classed themselves as participating in activity, and only 1 participant in the study group self-identified as sedentary. Although potentially a reflection of the broad definition of sports operationalized in this study, greater depth of activity profile information would be required to exclude the possibility of selection bias. Future studies should aim to collect a more comprehensive activity profile of participants, including their postoperative physical activity aspirations.

When the design and validation of patient-reported outcomes are considered, COSMIN recommendations are for >100 participants to be included. Cohort sizes of 50 to 90 participants are classed as adequate[18]; however, based on the low participant numbers in subgroups, robust conclusions could not be drawn regarding the ability of the scale to differentiate at multiple levels of the construct. The inadequate power increases the potential for type II error, although trends were consistent when assessed at initial assessment and 6 months. Further research is warranted in this area, as return to sports activity is not a binary outcome.[11]

CONCLUSION

This preliminary assessment of the psychometric properties of the HIP-RSI(sf) supports its use as a valid, reliable, and easily administered tool for assessing psychological readiness to return to sporting activity for patients after hip arthroscopy with a range of participation. The assessment of psychological milestones is intrinsic to facilitating a successful return to sporting activity. Evaluating psychological readiness, in addition to more commonly performed physical testing and patient's wishes, could enable early recognition of patients requiring adaptation of their rehabilitation programs to enable a successful transition back to sporting activity and the addition of appropriate psychological support and education when needed.

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PART D

OVERALL DISCUSSION AND THESIS CONCLUSIONS

CHAPTER 10 : THESIS SUMMARY, IMPLICATIONS AND CONCLUSION

The overall aim of this thesis was to investigate physical activity in patients following hip arthroscopy. This thesis used subjective and objective outcomes, and quantitative and qualitative methodologies, in order to capture a broad range of perspectives across different aspects of physical activity. An enhanced understanding of physical activity after hip arthroscopy will inform ongoing development of rehabilitation programmes supporting safe and effective return to physical activity.

This chapter summarises the overall thesis findings, clinical implications, strengths and limitations, future research directions and conclusions. The key findings are summarised in Figure 10.1.

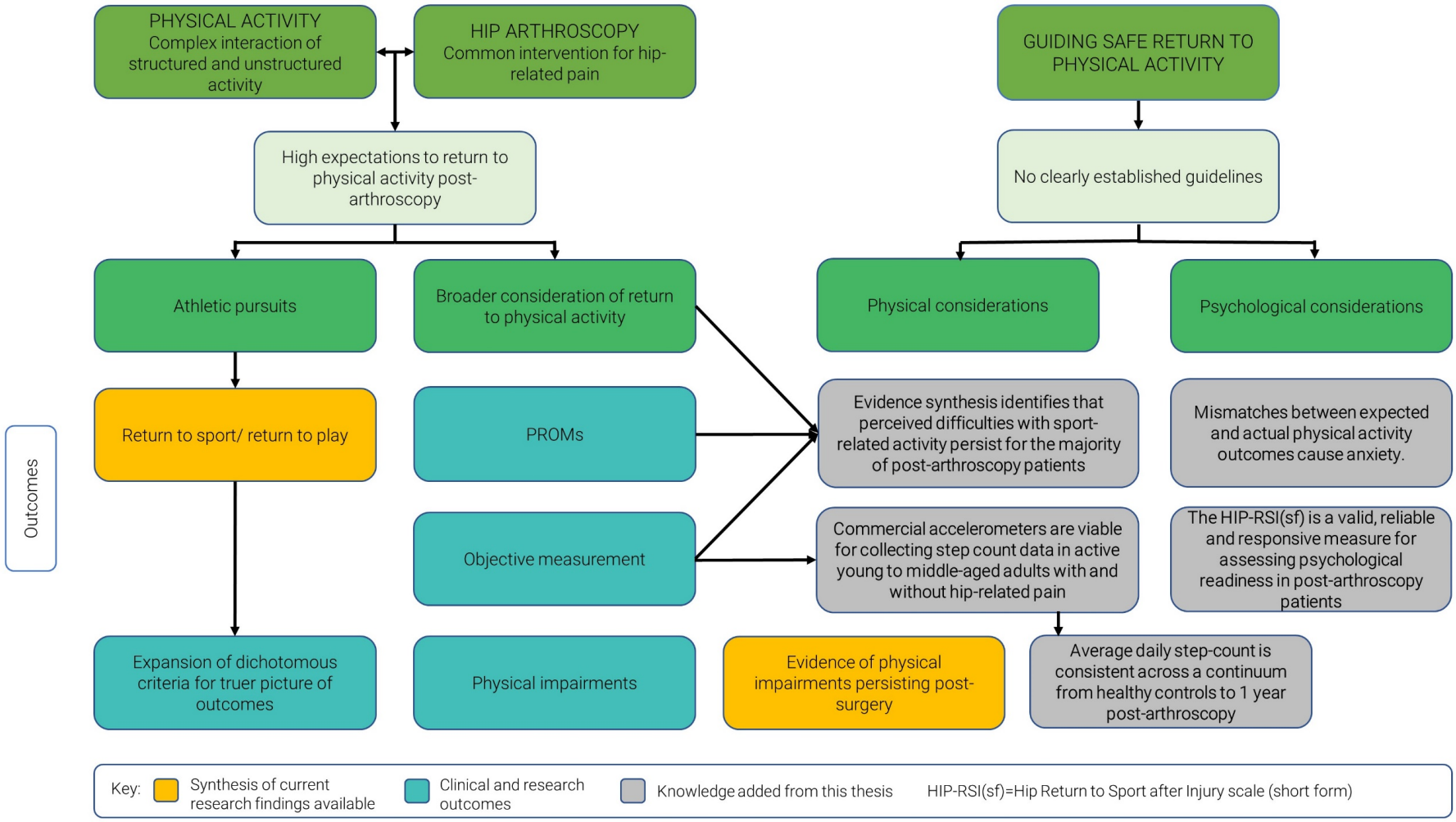

Figure 10.1. Overview of physical activity following hip-arthroscopy and knowledge gaps addressed in this thesis.

10.1 SUMMARY OF THESIS FINDINGS.

Physical activity is critical for physical and mental health[22], as it contributes significantly to social, physical and mental wellbeing. Physical activity is important for specific clinical populations, including young and middle-aged adults with hip-related pain, pre- or post-surgery[48, 203]. Physical activity is a potentially modifiable influence on the health of the hip joint, overall physical function and quality of life; as such, it is an important outcome to assess and address limitations in relation to interventions for hip-related pain.

A systematic review of the literature was undertaken in Study 1 (Chapter 3)[111], evaluating the current evidence pertaining to physical activity following hip arthroscopy. Several key points emerged from this review. Following hip arthroscopy, most patients felt better in relation to physical activity tasks and there was a trend towards improvement for all the patient-reported outcome measures (PROMs) utilised in the included studies; however, analysis of the most frequently used outcome measure identified that the majority of Hip Outcome Score-Sport Scale outcome data failed to record a level of improvement that would equate with 'feeling good' (a patient acceptable symptom state (PASS)), at either less than or more than one year post-arthroscopy. This finding indicates a need to carefully identify potential barriers and facilitators, both physical and psychological, to achieving a more satisfactory return to physical activity.

Although physical activity is an important outcome for this cohort[151, 152], it was evident from Study 1 (Chapter 3)[111] that it was poorly reported in the current literature. The PROMs identified as most appropriate for the cohort were infrequently used, limiting the scope and potential validity of the information available. The use of objective measures, such as step count data, and the use of accelerometers was only undertaken in one previous study[131]. This was for individuals undergoing hip arthroscopy for femoroacetabular impingement (FAI) syndrome, in which no increase of objectively measured physical activity was identified at one year post-operatively compared to pre-operatively, despite improvements in self-reported volume of physical activity. The apparent lack of correlation between the two modes of assessment highlighted the need for further investigation to add to the body of knowledge regarding objectively measured physical activity in this cohort.

In order to investigate the potential utility of commercial accelerometers (also known as fitness trackers, activity trackers or personal activity monitors), Studies 2 and 3 (Chapters 5 and 6)[110, 112] were undertaken. Study 2 (Chapter 5)[110] aimed to evaluate the validity of the Fitbit Flex™ for measuring step count at jogging and running speeds, as well as the inter-device reliability of these commercial accelerometers in a laboratory setting. As a frequently used research device, the ActiGraph GT3X+ was assessed as a comparative measure. Both the commercial (Fitbit flex™) and research-grade device

(Actigraph GT3X+) provided a valid account of steps taken at jogging and running speeds attainable by non-elite runners on a treadmill, illustrating their potential suitability for assessing step count in young to middle-aged adults for whom physical activity is likely to include higher speeds of ambulation.

Building on this data, Study 3 (Chapter 6)[112] investigated the accelerometers in a free-living environment. We examined potential errors incurred as commercial devices were superseded by the next model. This study also enabled practical elements of data collection, such as duration of data collection episodes and the application of cut-off points, to be tested for viability. Some variations were apparent between generations of Fitbit™; however, the 12% mean absolute percentage error (MAPE) for step count was deemed to be acceptable for use in 'real-life' data collection. The standard error of the mean (at 125 steps per day) represents a relatively small margin of error when considered within the context of the multiple influences potentially perturbing results in a free-living environment. In comparison, a MAPE of 38% was evident in relation to fairly/very active minutes recorded by the two generations of Fitbit™ device, with discrepancies increasing as duration of activity in this category lengthened. This result further validated findings from Study 2 (Chapter 5)[112] that step count was the most consistently reliable metric to compare in order to minimise the risk of bias between devices.

Studies 2 (Chapter 5)[110] and 3 (Chapter 6)[112] indicated that step count was the most reliable and valid metric and that two weeks of data collection gave an adequate return of data to meet commonly endorsed criteria for the number of days of data required to accommodate daily variability in step count[40, 238]. A cut-off point of 1,500 steps/day[241], while carrying the potential for error by lowering mean step count, provided a simple criterion to apply and yielded mean step counts comparable with previously published data[21, 37, 39].

Commercial accelerometers were used in Study 4 (Chapter 7) to measure the mean daily step count in four groups of participants sited at different points on the spectrum of hip disease, ranging from healthy controls to post-arthroscopy patients. No differences were found in relation to mean daily step count between healthy controls and three different cohort groups across the spectrum of hip disease, after adjusting for age and sex. This finding indicates that weight-bearing physical activity, which is important for hip-related health, is consistent across groups; however, deficits were identified in hip-related quality of life measures across symptomatic groups compared to previously established normative values[123]. The observed pattern aligns with previous studies[107, 131] and strengthens the premise that physical activity outcomes should encompass both objective and subjective measures as they capture different constructs/aspects of physical activity.

Study 1 (Chapter 3)[111] identified a trend of patients failing to reach a self-reported acceptable level of improvement for the Hip Outcome Score-Sport Scale post-arthroscopy. Study 4 (Chapter 7) identified

an apparent lack of parity between an objective measure of physical activity and perceived function; however, quantitative research designs do not enable us to understand the reasons for these findings. To explore the factors influencing participation in physical activity, qualitative interviews were undertaken with patients at six months post-hip arthroscopy. Study 5 (Chapter 8)[113] identified four key themes emerging from these interviews: a mismatch between expectations and actual progress during the first six months following surgery; a wide variation in physical activity undertaken at six months; sub-optimal psychological readiness and an associated emotional toll; and the influence of support and information provided around post-operative physical activity. Expectations of a shorter recovery period were common, irrespective of perceived physical activity ability at six months. Some participants reported receiving mixed messages from healthcare providers where perceived inadequacies in progress caused a significant emotional toll, exemplifying the interaction between all four themes. The study identified potential barriers and facilitators associated with returning to physical activity, highlighting opportunities to address modifiable factors through collaborative, realistic goal-setting and the provision of timely education and support.

The findings of Studies 4 (Chapter 5) and 5 (Chapter 6)[113] support the assertion that being physically and psychologically prepared to return to physical activity are not the same thing. This concept has been most closely observed in relation to anterior cruciate ligament reconstruction (ACLR)[11, 260, 261]. Although parallels do exist between cohorts undergoing ACLR and hip-arthroscopy patients, the nature of onset, most frequently traumatic for an ACL injury compared to the insidious onset most frequently associated with hip-related pain, may affect subsequent psychological impacts. Study 6 (Chapter 9)[114] aimed to determine the psychometric properties of the Hip-Return to Sport after Injury (short form) scale (HIP-RSI(sf)), developed from the Anterior Cruciate Ligament Return to Sport After Injury (ACL-RSI) scale[259], in patients post-hip arthroscopy returning to different levels of physical activity. This preliminary assessment of the psychometric properties of the HIP-RSI(sf) supported its use as a valid, reliable and easily-administered tool for assessing psychological readiness to return to sporting activity for patients following hip arthroscopy with a range of participation levels. Evaluating psychological readiness, in addition to more commonly performed physical testing and together with consideration of patient preferences, could enable early identification of patients requiring additional appropriate psychological support and education to enable a successful transition back to sporting activity.

10.2 IMPLICATIONS OF THESIS FINDINGS

"I am the sort of person that my mental well-being and happiness, through my whole life, has been closely linked to physical activity."

(Participant 3, Study 5 (Chapter 8)[113])

10.2.1 Clinical implications

The key clinical implications of this thesis pertain to improving the post-operative recovery journey to enable hip arthroscopy patients to achieve their best outcomes in relation to physical activity. From both a quantitative and qualitative perspective, insights from this thesis provide strategies that may be implemented to achieve this aim.

"..the pain was bad, but mentally, it was huge."

(Participant 10, Study 5 (Chapter 8)[113])

Perhaps one of the most striking features of this research was the level of anxiety and psychological distress related to returning to physical activity post-operatively, as highlighted in Study 5. Although it is established that both physical and psychological readiness are key to successfully returning to sport and recreational activity following injury or surgery[11, 190, 261], the traditional bias has been toward physical testing. The HIP-RSI(sf) (Study 6)[114] not only provides a valid, reliable and concise measurement tool, but also a framework for opening conversations around the potential emotional, cognitive and behavioural consequences of surgery. The assessment of psychological readiness could enable early recognition of patients requiring additional support to enable a successful transition back to desired physical activity. Failure to reach an expected balance between physical and psychological readiness may also act as a cue to instigate referral to health care professionals outside the physiotherapy scope of practice for appropriate psychological support and education when needed.

"…no one journey is the same…..everyone's journey is very different."

(Participant 11, Study 5 (Chapter 8)[113])

While research identifies commonalities in the population being investigated, individual treatment should address the novel and individually specific patient factors. Study 4 (Chapter 7) identified no

significant difference in step count at various post-operative time points during the first year post-surgery and an equivalent step count between participants at one year following surgery with healthy controls. Similarly, Kierkegaard et al. (2019)[131] found no significant changes in a range of accelerometry-based measures, which may have had the potential to be more sensitive in detecting differences, pre- to one year post-arthroscopy. Mean daily step count is a metric that is subject to high variation between individuals, as evidenced by the large standard deviations within this thesis and other studies[21]. This finding means that differences must be large at a group level to be statistically significant; however, when considering the rehabilitation of individual patients, step count has the potential to be a practical metric to include in education and rehabilitation strategies, particularly for those keen to use personal activity tracking. In this context, monitoring step count may act as a tool to reduce anxiety, guiding individualised goal-setting and enabling peaks and troughs of activity to be identified.

Patients should be reassured that their rehabilitation is a unique journey and that 'normal' is a wide-ranging attribute. Study 1 (Chapter 3)[111] and Study 4 (Chapter 7) add to the current evidence-base that suggests perceived deficits in physical activity continue to be evident more than one-year after surgery[123, 231]. Discussing this effect with patients may help to mitigate concerns if they perceive their progress to be 'abnormal'. Clinicians should also be prepared to support rehabilitation beyond the first stages of returning to activity.

"… it's good…. doing measurements so you can see you're getting some quantitative data as to how you're progressing."

(Participant 12, Study 5 (Chapter 8)[113])

Self-quantified perceptions of physical activity have been shown to be inconsistent in comparison to objective measures in post-hip arthroscopy cohorts[131] and younger patients (< 50 years of age) undergoing total hip arthroplasty (THA)[216]. Encouraging the use of personal activity trackers to monitor mean daily step count may facilitate a more robust perception of activity undertaken. Additionally, monitoring step-count may enable clinicians to address the wider concept of physical activity for health as part of clinical encounters. A recent consensus statement [234] recommended that discussing physical activity should be an intrinsic element of all consultations and that patients should be encouraged to monitor activity objectively. Monitoring physical activity in the same way as other assessment criteria, such as strength and range of movement, offers the opportunity to identify those who may be falling short of physical activity for health goals and enable clear and achievable physical activity-related goals to be built into rehabilitation programmes.

As identified in Studies 4 and 5, undertaking physical activity and how an individual may perceive their level of physical activity are only partially related constructs that merit individual measurement. The HIP-RSI(sf) provides a tool that can be used to measure progress in psychological readiness to return to activity. Where differences are identified between physical and psychological preparedness, the use of objective measures to quantify progress, alongside patient-specific problem-based goal-setting, may help to improve confidence, promote self-efficacy and reduce psychological barriers.

"I honestly thought that afterwards it would be like some magic cure"

(Participant 13, Study 5 (Chapter 8)[113])

A common misconception identified in Study 5 (Chapter 8)[113] was the likely timeline to achieving desired physical activity outcomes. Confusion in this area is easy to understand as predicted timelines vary considerably[53], as does the definition or individual perception of a successful return to activity[267]. Individual timelines will hinge on multiple variables, both intrinsic, such as age or underlying joint disease, and extrinsic, such as post-operative surgical protocols and the type and level of preferred activity. Clinical opportunities need to be utilised to ensure that realistic outcomes are identified, understood and reflective of personal preferences[97] as part of shared decision-making and education. As identified above, the use of both subjective and objective outcome monitoring can play a role in this process, working with patients in mutually agreed goal-setting to align expectations with reality.

Adequately managing patients' expectations for physical activity outcomes following both surgical and nonsurgical interventions for hip-related pain is challenging and may be best guided through a co-ordinated multidisciplinary effort. The process of aligning expectations and reality requires a collaborative and iterative process of education between clinical disciplines and patients, shared decision making forming an intrinsic element of both surgical and non-surgical intervention choices. Surgeons are recognised as key influencers in the decision-making process[23] and their positive endorsement of non-surgical management and education plays a vital role in facilitating informed decision making prior to seeking surgical consent.

"I didn't feel prepared for the outcome and the journey that I've had since the operation"

(Participant 10, Study 5 (Chapter 8)[113])

Tying all these threads together, evidence-based patient education, both pre- and post-arthroscopy, is key; however, clinicians need to be aware of the barriers to understanding that patients may face, as identified by participants in Study 5 (Chapter 8)[113], particularly when information was delivered in relatively stressful clinical contexts and in large quantities. Education processes should develop beyond the first clinical consultation and be modified to accommodate changing needs over time. Linking education opportunities to goal-setting, as identified above, and reinforcing verbal communication with written and/or visual information facilitates learning. The use of a range of outcome measures provides the opportunity to log information, reflect on and respond to change during rehabilitation. Clear communication, both with patients and inter-professionally, is vital to facilitate unambiguous messages being given to patients and an effective transition back to desired physical activity.

10.2.2 Research implications

The study findings reported in this thesis have implications for future research. For example, the importance of psychological milestones in assessing the effectiveness of hip-arthroscopy in returning individuals to their desired physical activity should be considered in research as well as clinical settings. The HIP-RSI(sf) could be used to achieve this aim. As a measurement tool, it presents a minimal extra burden to both participants and researchers. Criteria have been established for interpreting the scale, including the minimal detectable difference (MDD), standard error of measurement and the minimal important change (MIC).

Both objective and subjective physical activity data should be monitored, as the two methods provide different but complementary perspectives of this complex construct. Similarly, the limited activity profile of participants presented in research studies restricts our understanding of physical activity outcomes. A more comprehensive profile, moving beyond athletic classification, has the potential to provide a more complete picture of changes in physical activity status and the impact of interventions. While specific questions may need to be asked regarding the type of activity undertaken, future studies may consider objective measurements of physical activity, using classification categories such as those based on step count as an indication of purposeful activity undertaken across domains[242].

Commercial devices, such as Fitbits™, offer a viable option for collecting objective data in research studies. This thesis has outlined some aspects of using these devices that may be considered when designing studies. Young to middle-aged adults with hip-related pain, pre- or post-surgery are likely to participate in higher cadence ambulatory activities, such as brisk walking, jogging and running, across

different domains of physical activity. Fitbit™ devices proved valid and reliable for step count at jogging and running speeds with an equivalent output to research-grade devices in a laboratory-based setting, improving confidence in their use for these more active cohorts.

There will be greater variation in all accelerometry outputs, whether from research-grade or commercial devices, when used in free-living environments compared to the constrained environment of laboratory-based studies. This thesis offers some criteria researchers can use to inform their decision-making on the suitability of commercial devices to achieve their study aims. Studies using commercial devices need to be designed to accommodate a degree of uncertainty. Research-grade devices offer access to raw data and the research team is responsible for downloading and applying algorithms to the data. This control and transparency does not exist with commercial devices, where study participants take on responsibility for charging devices and downloading pre-processed data. Despite this shift in roles, Study 3 (Chapter 6)[112] shows an equivalent rate of data retrieval from research- and commercial-grade devices. To achieve this, mechanisms need to be in place for research teams to access the data, either through the device interface, as exemplified in this thesis, or using third-party platforms.

Feasibility may be uncertain when using commercial devices if recruitment takes place over a protracted period of time, or where devices need to be replaced in longitudinal studies due to variation between different generations of devices. Findings from Study 3 (Chapter 6)[112] provide an indication of the degree of variation that can be expected between generations of a device from the same manufacturer. The impact of this variation can be minimised by basing primary analysis on step-count and ensuring that devices are worn in the same anatomical position. Research teams may consider undertaking small-scale studies to quantify the potential margin of error for different devices. The drop-out rates identified in Study 4 (Chapter 7) can be used to inform sample-size calculations and the data management decisions used in this thesis can be carried forward to future studies.

10.3 Strengths and limitations

Study-specific strengths and limitations are discussed in each chapter; the following section provides an overview of strengths and limitations in relation to the whole thesis.

A key strength of the research program reported in this thesis has been the use of a range of methodologies, enabling the research questions to be addressed from different perspectives. Each method has contributed to collectively providing a more comprehensive picture of physical activity following hip-arthroscopy. The findings of this thesis enhance our ability to assess physical activity as an outcome. They may also support effective rehabilitation by establishing the potential to use

commercial accelerometers with this cohort and providing a valid and reliable tool to assess psychological readiness to return to physical activity and sport.

The mixed-methods approach undertaken added diversity and depth to the data presented. Qualitative research has been identified as important for expanding understanding of quantitative research findings, providing a complementary knowledge base to support the broad-based reasoning approach required in clinical practice[188]. Certainly, the findings in Study 5 (Chapter 8)[114] provide individual perspectives and thus novel insights into potential barriers to progressing from 'feeling better' to 'feeling good' following hip arthroscopy, particularly in relation to physical activity, as identified in Study 1 (Chapter 3)[111].

The research programme was grounded in an extensive systematic review undertaken according to PRISMA guidelines[167] enabling high-quality, transparent reporting of previous findings. The potential bias associated with the predominance of observational studies reporting physical activity outcomes following hip-arthroscopy was considered a priori. A specifically developed appraisal tool included biases relevant to observational studies in general and those specific to the review[196]. Despite these measures, the generalisability of the findings may be compromised by the quality of the available studies.

A further strength of this thesis was the consideration of PASS scores undertaken in Study 1 (Chapter 3) and Study 4 (Chapter 7). This cut-off point has the advantage of potentially being less sensitive to baseline symptoms than other measures of interpretability[239] and reflects a clinically relevant treatment goal[35]. The compilation of data within Study 1 (Chapter 3), presented against the criteria for 'feeling better' or 'feeling good', provides an easily interpretable appraisal of post-arthroscopy outcomes; however, it was drawn from the Hip Outcome Score (HOS), as the most frequently occurring PROM in the included studies. Although this score has some suitable psychometric properties established for post-hip arthroscopy patients[155-157], recent studies do not rank it as the most suitable measure for this cohort[105, 123, 233].

More than one type of Fitbit™ device was used in this thesis, which reflected real-life changes occurring in the commercial market over the course of data collection. Confidence in the comparability of data was increased by only reporting step count data rather than more variable metrics and ensuring the same protocols were adhered to across devices. The strength of using step count as a metric includes its ease of interpretation, its well-established associations with health variables[15, 138, 240] and that it facilitates comparison with other studies. Metrics, such as time spent at different activity levels, are prone to greater margins of error and are defined variably by different manufacturers. Further limitations were imposed by the burden associated with the use of activity trackers. Some participants

requested to use their own personal activity trackers, meaning the devices supplied by the research team represented an extra burden. In future studies, there may be a place for participants to use their own devices, if broadly comparable for research requirements (e.g. all devices are wrist-worn). To facilitate this idea, ethically acceptable ways of accessing data need to be established in the planning stages.

A further strength of this thesis is the wide range of physical activity undertaken by participants which improves the generalisability of results within a broad, young to middle-aged population. However, the range does present limitations in interpreting results for specific populations, such as elite athletes, for whom the use of accelerometers may present different challenges and for whom psychological influences may differ considerably.

For data pertaining to symptomatic subjects, participants within the thesis were sub-sets of ongoing longitudinal studies (one randomised clinical trial[125] and two observational cohort studies[44, 207]). This is an added strength, with the expansion of recruitment potential and the inclusion of three high-volume arthroscopy centres. Limitations imposed by this approach included varying numbers and participants within individual studies, related to the burden and nature of the commitment participants were required (and consented) to undertake. This method impacted most profoundly on post-arthroscopy longitudinal data collection, compromising the ability to assess changes in step count over time for this cohort. Additionally, data were not collected from participants prior to undergoing surgery which is essential to more fully identify cause and effect.

Further limitations include a maximum post-operative time frame of approximately one year. While this duration is likely to encapsulate the period of greatest change and greatest involvement with health care providers, improvements may continue to be gained over a longer time-frame[132] and assessment of physical activity over longer durations is warranted in future research. Additionally, no formal cost analysis was undertaken as part of this thesis such that no conclusions can be drawn in relation to the relative cost of using commercial rather than research-grade devices. Although the purchase cost of basic commercial accelerometers is less than research-grade devices, the relative staffing and administration costs are less easily predicted.

Despite these limitations, this thesis has provided an insight into clinically relevant tools to guide the return to physical activity for young to middle-aged adults after hip arthroscopy. The study has established the potential use of consumer activity trackers and is the first to present a valid and reliable score to appraise psychological readiness in this cohort.

10.4 FUTURE RESEARCH DIRECTIONS

The findings of this thesis provide a direction for further research to improve our knowledge base in this area and implement strategies to improve patient outcomes.

Study 6 (Chapter 9)[114] provided a preliminary assessment of reliability, validity, responsiveness and interpretability for the HIP-RSI(sf), which can be used to provide further insights into the influence of psychological readiness on a successful return to desired physical activity following hip arthroscopy. Assessing the psychometric properties of an outcome measure is an ongoing process, requiring multiple research efforts involving different settings and different cohorts[192]. Recent research has further improved our understanding of the psychometric properties of a Swedish version of the scale, undertaking an investigation of content validity with participants who had undergone arthroscopy for FAI syndrome[268]. This investigation of content validity suggested that additional questions relating to fear of pain and future hip health may merit inclusion. Many opportunities exist to further expand the clinimetric evidence supporting use of the scale, including population-specific content validity evaluation and assessment using more homogenous cohorts, such as at a specific time point post-surgery or with elite athletes. The scale should also be investigated in non-surgical cohorts undergoing interventions for hip-related pain to assess physical and psychological milestones during rehabilitation.

The use of accelerometers can also be considered in future research. The potential utility and impact of using personal activity trackers within rehabilitation, as an educational or motivational device, warrants further investigation. Additionally, it is evident that comprehensive physical activity profiles of participants are often inadequate in research studies. The routine collection of step count data may mitigate this shortfall. Many research studies undertaken are retrospective in nature. While these studies only represent level IV evidence, collated patient data could be used to improve our understanding of post-arthroscopy outcomes. To improve knowledge, the systematic and standardised collection of high-quality outcome measures would facilitate the pooling of information over a wider range of sources, from individual practitioners to specialist centres. Recent initiatives aiming to unite research efforts in providing guidance for the standardised measurement of physical capacity[171] and the use of PROMs[105] for young to middle-aged adults with hip-related pain can be implemented when treating individual patients, building databases or developing primary research. Though a consistent approach and the use of appropriate outcomes, predictors for a successful return to desired physical activity may be identified.

Although this thesis provides an initial step in presenting a patient perspective, patient-partnerships can be developed for further directing future research. Several participants suggested value in undertaking further qualitative interviews at one year post-operatively. The findings from Study 5

(Chapter 8)[113] could be used as a framework in developing an appropriately focused interview schedule with additional prompt questions to enable any new themes, relevant to the extended time frame, to emerge. Previous participants could be approached at the planning stages of future research projects to maintain relevance to the patient group. The development of educational resources is an opportunity for patients, researchers and clinicians to work in partnership. The potential barriers and facilitators to achieving an effective transition back to physical activity, identified in Study 5 (Chapter 8)[113], provide a starting point for the development of post-arthroscopy resources. Ongoing research should investigate the impact of such resources on the mismatch between expectations, physical activity outcomes and subsequent anxieties, as identified in Study 5 (Chapter 8)[113].

10.5 Conclusions

Hip arthroscopy is commonly undertaken by patients who have high expectations that surgery will address pre-operative deficits in physical activity. Attaining desired physical activity goals following surgery is important for health and wellbeing and for these young to middle-aged individuals to be able to fulfil their societal roles.

Through a systematic review, it was identified that perceived impairments in physical activity persist for most post-arthroscopy patients, that little objective data existed and that commercial accelerometry had not been used to measure physical activity in this cohort. Validity and reliability parameters were established for the use of commercial accelerometers with active young to middle-aged adults. Using mean daily step count as a proxy measure for physical activity across different domains, no significant differences were evident in activity between a healthy control group and participants at one year post-arthroscopy or non-surgical participants with hip-related pain, despite deficits identified in hip-related quality of life between symptomatic participants and healthy controls. Qualitative interviews undertaken at six months post-arthroscopy highlighted the psychological burden experienced in returning to physical activity, with a mismatch between expected and actual outcomes during this period. Psychological readiness to return to physical activity had previously been unexplored following hip arthroscopy. Appropriate clinometric properties were established for the HIP-RSI(sf) providing a framework for ongoing research in this area. An overview of thesis findings is included as an infographic (Figure 10.2).

The findings of this thesis enhance our understanding of the potential barriers and facilitators that patients may experience in making a successful transition back to their desired level of physical activity following hip arthroscopy. The complexity of the construct of physical activity requires the assessment of both objective and subjective measures. Tools now exist for the measurement of both physical and psychological progress during rehabilitation and to support ongoing research.

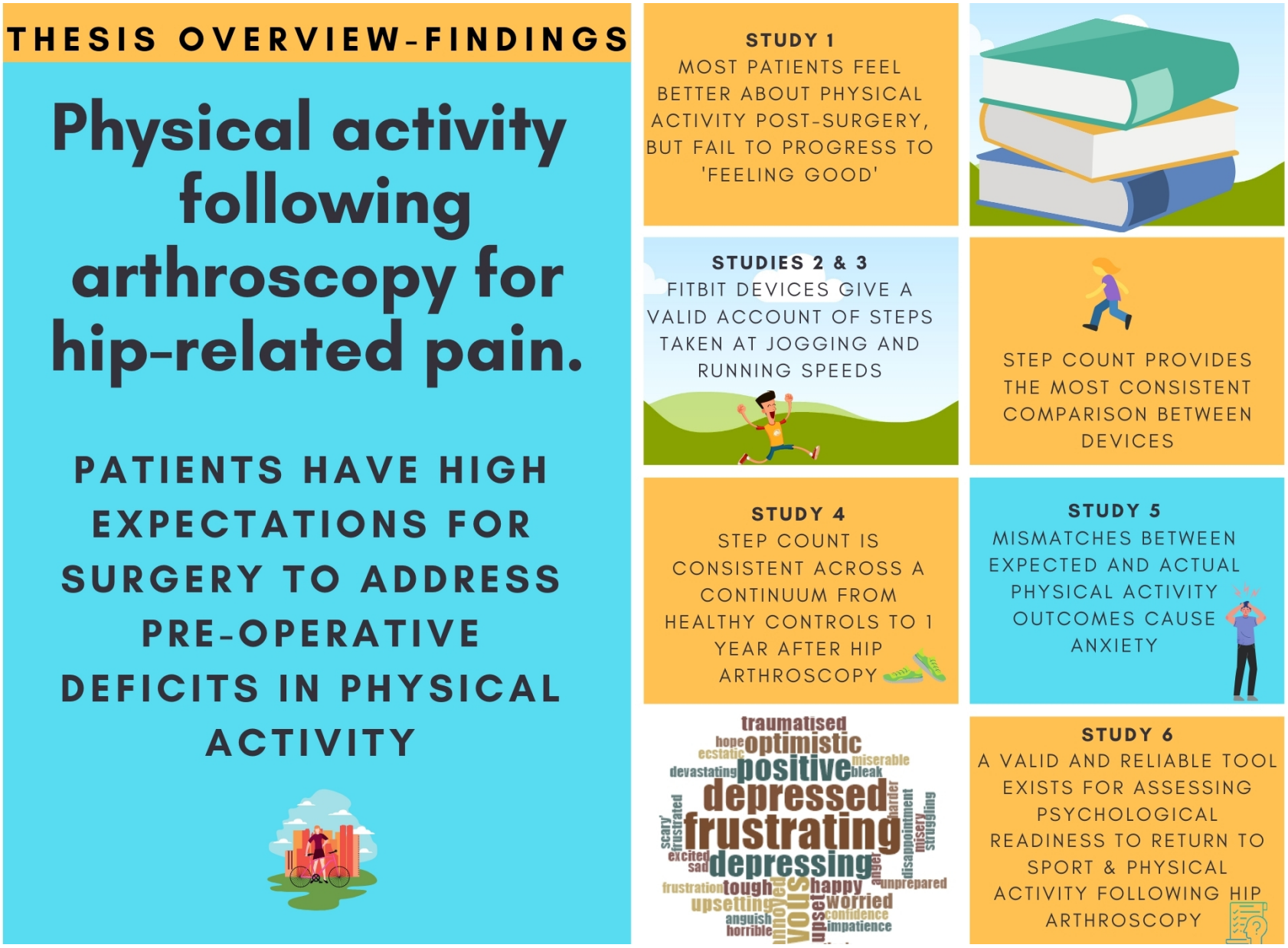

Figure 10.2. Overview of thesis findings.

APPENDICES

APPENDIX 1: COPYRIGHT PERMISSION STATEMENT

Study 1[111]

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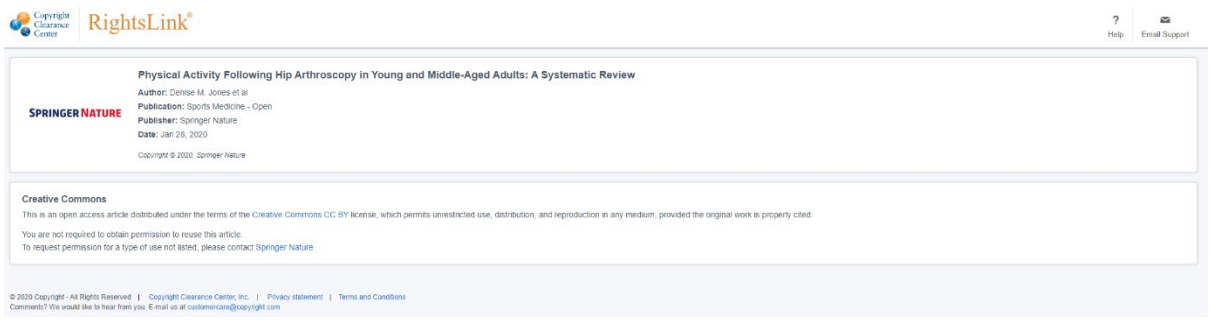

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Physical Activity Following Hip Arthroscopy in Young and Middle-Aged Adults: A Systematic Review

Author: Denise M. Jones et al
Publication: Sports Medicine - Open
Publisher: Springer Nature
Date: Jan 28, 2020

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Study 2[110]

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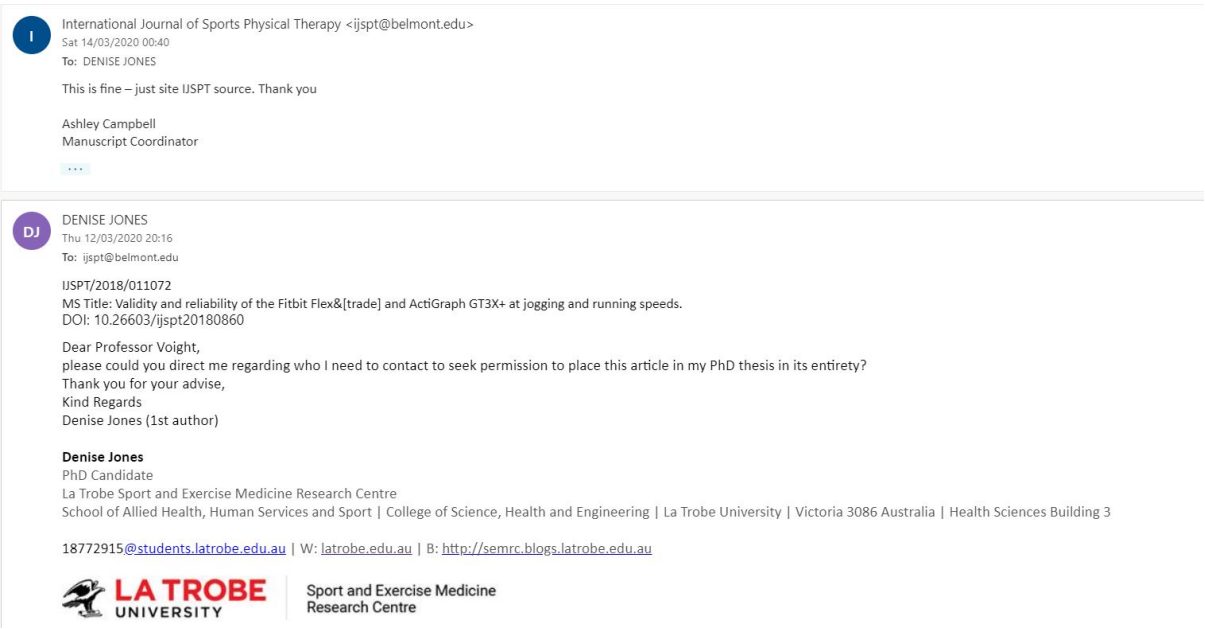

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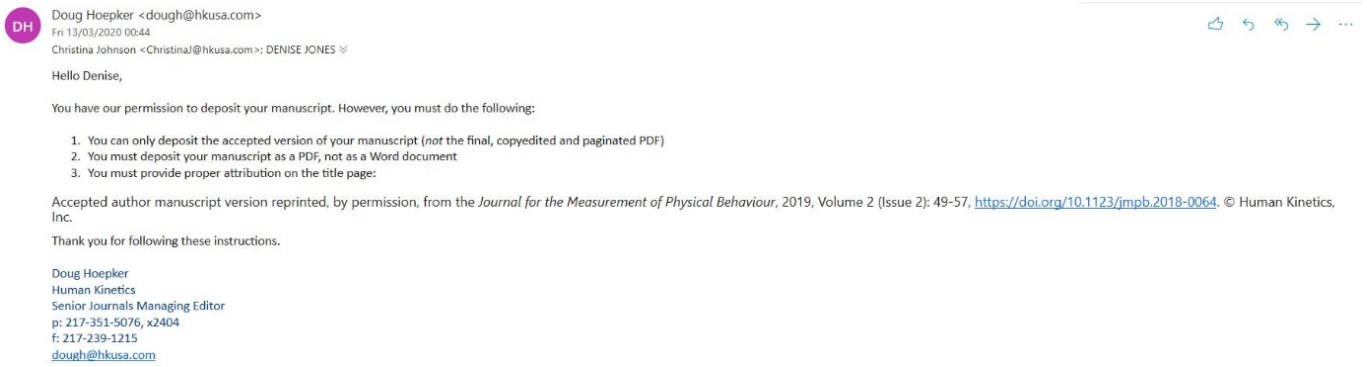

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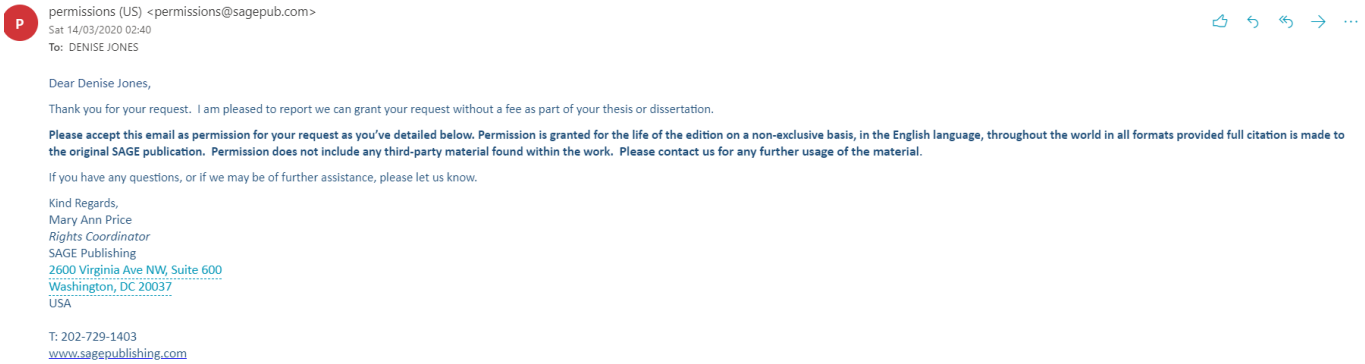

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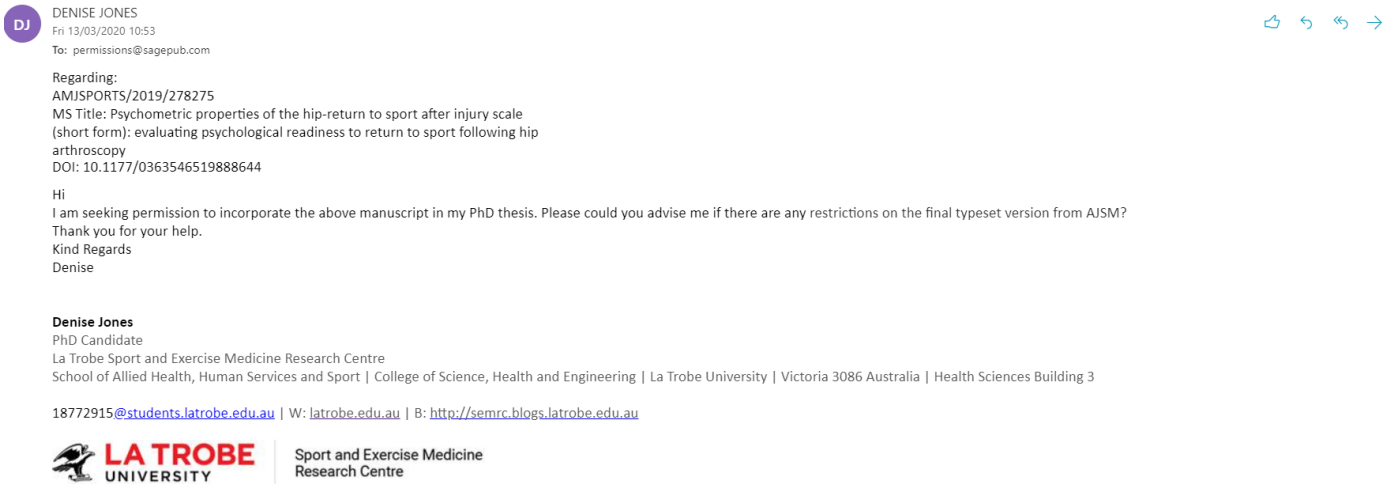

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APPENDIX 2: ADDITIONAL FILES, STUDY 1[111]

Additional file 1 – Example search strategy

Database: Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) <1946 to Present>

Search Strategy:

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1 Arthroscopy/ (22499)

2 arthroscop*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (32973)

3 Hip/ (11702)

4 Hip Joint/ (26682)

5 hip.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (147662)

6 hip joint.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (33071)

7 Exercise/ (93177)

8 physical activit*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (94198)

9 exercis*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (345891)

10 sport*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (91469)

11 Sports/ (29427)

12 athlet*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (77683)

13 Adult/ or Young Adult/ (4897986)

14 adult*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (5570417)

15 13 or 14 (5570417)

16 7 or 8 or 9 or 10 or 11 or 12 (493029)

17 1 or 2 (32973)

18 3 or 4 or 5 or 6 (147662)

19 17 and 18 (2755)

20 15 and 16 and 19 (247)

21 "hip arthroscop*".mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1481)

22 (hip adj5 arthroscop*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1823)

23 19 or 21 or 22 (2755)

24 15 and 16 and 23 (247)

25 15 and 23 (1202)

Additional file 2 – Study quality assessment forms

Additional File 2. Study quality assessment

A- Single arm study

			Question	Guidance	Response [Delete as appropriate]	Notes
External Validity						
	1	Representative	Is the sample representative of the population from which they were recruited?	To facilitate this, a study needs to identify the source of the population and describe how the participants are selected (explicitly defined inclusion / exclusion criteria).	✓ the sample is representative of the population from which they were recruited. **X** not representative or insufficient information for this judgement to be made.	
	2	Participation rate	Did the majority of 'recruited and eligible' participants take part in the data collection?	Calculated as the number of potential participants who are eligible to take part in the study that are then included in the initial sport/activity analysis. i.e. Loss of participants between establishing eligibility (having been recruited) and data collection	✓ percent participation was 80% or more **X** less than 80% recruited and eligible start data collection	
Internal Validity						
Performance Bias	**3**	Direct observation	Were the data collected directly from the subjects?	As opposed to by proxy - e.g. sport participation data may be reported by coach or from match statistics.	✓ if **all** sports/activity outcomes reported are collected directly from subjects **X** all data not collected directly from subjects	
Detection Bias	**4**	PROM – validity / reliability	Are the data collection tools used established as valid and reliable for the population being assessed?	The PROM used has been reported in the paper as having adequate reliability and validity, e.g. test-retest, piloting, validation in a previous study, with references included.	✓ if a this is established **and** reported **X** not established and reported **NA** no PROM's used	
	5	Direct observation, (objective measures)	Are the data collection tools used established as valid and reliable for the population being assessed?	The data collection tool used has been reported in the paper as having adequate reliability and validity, e.g. test-retest, piloting, validation in a previous study, with references included.	✓ if a this is established and reported. **X** not established and reported **NA** no direct measure of PA used that is not a PROM	
	6	Blinded assessors	Were those responsible for assessing data blinded?		✓ indicates that assessors were blinded. **X** if no or unable to establish.	
	7	Outcome measure	Was the same outcome measure used for all participants?		✓ indicates same method of ascertainment was used for all participants **X** same method of ascertainment was not used for all participants	
Attrition	**8**	Completeness	Do all the participants entering data collection reach the results section?	There is clear accounting for participant numbers within the results.	✓ percentage of participants in the final analysis was 80 or more, or a full description of those lost to follow-up was not suggestive of bias. **X** <80% in final analysis, unaccounted for or suggestive of bias	

			Question	Guidance	Response [Delete as appropriate]	Notes
Selection bias/control of confounding	9	Age	Are all participants within the age **range** of 18-50?		✓ if **range** within 18-50 **X** if range is outside 18-50 and not adjusted for in analysis or insufficient information for judgement to be made.	
	10	Location	Are participants from a comparable location?	It is identified that all participants are from a location that offers comparable facilities for care	✓ if the location of participants is comparable. **X** not comparable or unknown	
	11	Gender	Is there a balance of genders in the included cases?	Analysis identifies a balance of men and women participants or is adjusted for in analysis / reporting	✓ if gender is balanced (10% or less difference) or adjusted for in analysis **X** ->10% difference not adjusted for in analysis or insufficient information for this judgement to be made.	
	12	Severity of joint disease - OA	Is OA identified in the study?	Degree of OA has been screened for, however, some studies did not have sufficient information to enable a decision to be made, these need to be identified.	✓ if severity of OA identified in the study X insufficient information for this judgement to be made/OA severity not reported.	
	13	Follow-up	Are the time points at which the outcome is measured the same for all participants?	Assessment of point at which data is collected in relation to surgery or other pre-defined time point such as symptom onset /unable to participate in sport, if this is the primary end point instead of surgery	✓ where FU is the same for all study participants or lies within 10% i.e. the following acceptable ranges – 1 year follow-up, 1 month each way; 2 years follow-up = 2 months; 3 years follow-up = 3months……10 years = 10 months. **X** where FU differs by >10% or insufficient information for this judgement to be made	

B- Multiple arm study

			Question	Guidance	Response [delete as appropriate]	Notes
External Validity						
	1	Representative	Is the sample representative of the population from which they were recruited?	To facilitate this, a study needs to identify the source of the population and describe how the participants are selected (explicitly defined inclusion / exclusion criteria).	✓ the sample is representative of the population from which they were recruited. **X** not representative or insufficient information for this judgement to be made.	
	2	Participation rate	Did the majority of 'recruited and eligible' participants take part in the data collection?	Calculated as the number of potential participants who are eligible to take part in the study that are then included in the initial sport/activity analysis. i.e. Loss of participants between establishing eligibility (having been recruited) and data collection unless accounted for (e.g. loss as part of matching process)	✓ percent participation was 80% or more **X** less than 80% recruited and eligible start data collection	
Internal Validity						

			Question	Guidance	Response [delete as appropriate]	Notes
Performance Bias	3	Direct observation	Were the data collected directly from the subjects?	As opposed to by proxy - e.g. sport participation data may be reported by coach or from match statistics.	✓ if **all** sports/activity outcomes reported are collected directly from subjects **X –** all data not collected directly from subjects	
Detection Bias	4	PROM – validity / reliability	Are the data collection tools used established as valid and reliable for the population being assessed?	The PROM used has been reported in the paper as having adequate reliability and validity, e.g. test-retest, piloting, validation in a previous study, with references included.	✓ if a this is established **and** reported **X** not established and reported **NA** no PROM's used	
	5	Direct observation, (objective measures)	Are the data collection tools used established as valid and reliable for the population being assessed?	The data collection tool used has been reported in the paper as having adequate reliability and validity, e.g. test-retest, piloting, validation in a previous study, with references included.	✓ if a this is established and reported. **X** not established and reported **NA –** no direct measure of PA used that is not a PROM	
	6	Blinded assessors	Were those responsible for assessing data blinded?		✓ indicates that assessors were blinded. **X** if no, or unable to establish.	
	7	Outcome measure	Was the same outcome measure used for all participants?		✓ indicates same method of ascertainment was used for all participants **X** same method of ascertainment was not used for all participants	
Attrition	8	Completeness	Do all the participants entering data collection reach the results section?	There is clear accounting for participant numbers within the results.	✓ percentage of participants in the final analysis was 80 or more, or a full description of those lost to follow-up was not suggestive of bias. **X** <80% in final analysis, unaccounted for or suggestive of bias	
Selection bias/control of confounding	9	Age	Is there a significant difference in the age profile of the compared groups? Are all participants within the age **range** of 18-50?	Analysis identifies that the comparison groups are not statistically different. Sufficient data needs to be available to enable this analysis if not undertaken by authors.	✓ if age is balanced between groups (10% or less difference) or adjusted for in analysis and range lies between 18-50. **X** if >10% difference or range is outside 18-50 or insufficient information for judgement to be made.	
	10	Location	Are compared groups from comparable location?	It is identified that compared groups are from a location that offers comparable facilities for care.	✓ if the location of comparison groups is comparable. **X** not comparable or unknown	
	11	Gender	Is there a significant difference in the number of men and women in the compared groups?	Analysis identifies that the comparison groups are not statistically different. Sufficient data needs to be available to enable this analysis if not directly reported	✓ if gender is balanced between groups (10% or less difference) or adjusted for in analysis. **X** if >10% or insufficient information for this judgement to be made.	
	12	Severity of joint disease - OA	Is OA identified in the study?	Degree of OA has been screened for, however, some studies did not have sufficient information to enable a decision to be made, these need to be identified.	✓ if severity of OA identified in the study **X** insufficient information for this judgement to be made/OA severity not reported.	

			Question	Guidance	Response [delete as appropriate]	Notes
	13	Follow-up	Are the time points at which the outcome is measured the same for both groups?	Assessment of point at which data is collected in relation to surgery or other pre-defined time point such as symptom onset /unable to participate in sport, if this is the primary end point instead of surgery.	✓ where FU is the same for all study participants or lies within 10% i.e. the following acceptable ranges – 1 year follow-up, 1 month each way; 2 years follow-up = 2 months; 3 years follow-up = 3months……10 years = 10 months. **X** where FU differs by >10% or insufficient information for this judgement to be made.	

Additional file 3 – Studies excluded at full text screen

Additional file 3: Studies excluded at full text screen

Author	Year	Title
Greater than 10% of cohort with OA		
Awan, N.;Murray, P.;	2006	Role of hip arthroscopy in the diagnosis and treatment of hip joint pathology
Brunner, Alexander;Horisberger, Monika;Herzog, Richard F.;	2009	Sports and Recreation Activity of Patients With Femoroacetabular Impingement Before and After Arthroscopic Osteoplasty
Byrd, J. W.;Jones, K. S.;	2009	Hip arthroscopy in athletes: 10-year follow-up
Geyer, Mark R.;Philippon, Marc J.;Fagrelius, Theodore S.;Briggs, Karen K.;	2013	Acetabular Labral Reconstruction With an Iliotibial Band Autograft: Outcome and Survivorship Analysis at Minimum 3-Year Follow-up
Menge, Travis J.;Briggs, Karen K.;Dornan, Grant J.;McNamara, Shannen C.;Philippon, Marc J.;	2017	Survivorship and Outcomes 10 Years Following Hip Arthroscopy for Femoroacetabular Impingement: Labral Debridement Compared with Labral Repair
Murata, Y.;Uchida, S.;Utsunomiya, H.;Hatakeyama, A.;Nakamura, E.;Sakai, A.;	2017	A Comparison of Clinical Outcome between Athletes and Nonathletes Undergoing Hip Arthroscopy for Femoroacetabular Impingement
Sansone, M.;Ahlden, M.;Jonasson, P.;Thomee, C.;Sward, L.;Collin, D.;Baranto, A.;Karlsson, J.;Thomee, R.;	2016	Outcome of hip arthroscopy in patients with mild to moderate osteoarthritis-A prospective study
Skendzel, Jack G.;Philippon, Marc J.;Briggs, Karen K.;Goljan, Peter;	2014	The Effect of Joint Space on Midterm Outcomes After Arthroscopic Hip Surgery for Femoroacetabular Impingement
Tjong, V. K.;Gombera, M. M.;Kahlenberg, C. A.;Patel, R. M.;Han, B.;Deshmane, P.;Terry, M. A.;	2017	Isolated Acetabuloplasty and Labral Repair for Combined-Type Femoroacetabular Impingement: Are We Doing Too Much?
No suitable physical activity outcome available		
Becker, Lindsay C.;Carter-Kelley, Stephanie;Ellis, Thomas;Cenkus, Kathleen;Di Stasi, Stephanie L.;	2015	Pre-operative low back pain negatively affects self-reported function in individuals undergoing hip arthroscopy
Bretschneider, H.;Trattnig, S.;Landgraeber, S.;Hartmann, A.;Gunther, K. P.;Dienst, M.;Schroder, J.;Fickert, S.;	2019	Arthroscopic matrix-associated, injectable autologous chondrocyte transplantation of the hip: significant improvement in patient-related outcome and good transplant quality in MRI assessment
Byrd, J. W.;Jones, K. S.;Chin, P. C.;	2016	Hip arthroscopy: a report on a cohort of orthopaedic surgeons
Cetinkaya, S.;Toker, B.;Ozden, V. E.;Dikmen, G.;Taser, O.;	2016	Arthroscopic labral repair versus labral debridement in patients with femoroacetabular impingement: a minimum 2.5 year follow-up study
Domb, B. G.;Gupta, A.;Dunne, K. F.;Gui, C.;Chandrasekaran, S.;Lodhia, P.;	2015	Microfracture in the Hip: Results of a Matched-Cohort Controlled Study with 2-Year Follow-up
Farjo, L. A.;Glick, J. M.;Sampson, T. G.;	1999	Hip arthroscopy for acetabular labral tears
Gigi, R.;Rath, E.;Sharfman, Z. T.;Shimonovich, S.;Ronen, I.;Amar, E.;	2016	Hip Arthroscopy for Femoral-Acetabular Impingement: Do Active Claims Affect Outcomes?
Grammatopoulos, George;Davies, Owain L. I.;El-Bakoury, Ahmed;Gill, Harinderjit S.;Pollard, Tom C. B.;Andrade, Antonio J.;	2017	A Traffic Light Grading System of Hip Dysplasia to Predict the Success of Arthroscopic Hip Surgery
Hartig-Andreasen, C.;Nielsen, T. G.;Lund, B.;Soballe, K.;Lind, M.;	2017	Outcome after arthroscopic labral surgery in patients previously treated with periacetabular osteotomy: a follow-up study of 43 patients
Joseph, Roody;Pan, Xueliang;Cenkus, Kathleen;Brown, Lindsey;Ellis, Thomas;Di Stasi, Stephanie;	2016	Sex Differences in Self-Reported Hip Function Up to 2 Years After Arthroscopic Surgery for Femoroacetabular Impingement

Kalisvaart, M. M.;Safran, M. R.;	2017	Hip instability treated with arthroscopic capsular plication
Kamath, A. F.;Componovo, R.;Baldwin, K.;Israelite, C. L.;Nelson, C. L.;	2009	Hip arthroscopy for labral tears: Review of clinical outcomes with 4.8-year Mean follow-up
Kemp, Joanne;Makdissi, Michael;Schache, Anthony;Finch, Caroline;Pritchard, Michael;Crossley, Kay;Kemp, Joanne L.;Schache, Anthony G.;Finch, Caroline F.;Pritchard, Michael G.;Crossley, Kay M.;	2016	Is quality of life following hip arthroscopy in patients with chondrolabral pathology associated with impairments in hip strength or range of motion?
Knapik, D. M.;Sheehan, J.;Nho, S. J.;Voos, J. E.;Salata, M. J.;	2018	Prevalence and Impact of Hip Arthroscopic Surgery on Future Participation in Elite American Football Athletes
Lee, Simon;Frank, Rachel M.;Harris, Joshua;Song, Sang Hoon;Bush-Joseph, Charles A.;Salata, Michael J.;Nho, Shane J.;	2015	Evaluation of Sexual Function Before and After Hip Arthroscopic Surgery for Symptomatic Femoroacetabular Impingement
Matsuda, D. K.;Kivlan, B. R.;Nho, S. J.;Wolff, A. B.;Salvo, J. P., Jr.;Christoforetti, J. J.;Ellis, T. J.;Carreira, D. S.;	2019	Arthroscopic Outcomes as a Function of Acetabular Coverage From a Large Hip Arthroscopy Study Group
Matsuda, D. K.;Wolff, A. B.;Nho, S. J.;Salvo, J. P., Jr.;Christoforetti, J. J.;Kivlan, B. R.;Ellis, T. J.;Carreira, D. S.;	2018	Hip Dysplasia: Prevalence, Associated Findings, and Procedures From Large Multicenter Arthroscopy Study Group
McCarthy, J.;Barsoum, W.;Puri, L.;Lee, J. A.;Murphy, S.;Cooke, P.;	2003	The role of hip arthroscopy in the elite athlete
Mei-Dan, O.;McConkey, M. O.;Knudsen, J. S.;Brick, M. J.;	2014	Bilateral hip arthroscopy under the same anesthetic for patients with symptomatic bilateral femoroacetabular impingement: 1-year outcomes
Mullins, K.;Hanlon, M.;Carton, P.;	2019	Arthroscopic correction of femoroacetabular impingement improves athletic performance in male athletes
Nielsen, T. G.;Miller, L. L.;Lund, B.;Christiansen, S. E.;Lind, M.;	2014	Outcome of arthroscopic treatment for symptomatic femoroacetabular impingement
Pontiff, M.;Ithurburn, M. P.;Ellis, T.;Cenkus, K.;Stasi, S. D.;	2016	Pre- and post-operative self-reported function and quality of life in women with and without generalized joint laxity undergoing hip arthroscopy for femoroacetabular impingement
Renouf, J.;Pergaminelis, N.;Tran, P.;Fary, C.;Tirosh, O.;	2019	The outcome of arthroscopic repair of acetabular labral tears using the iHOT-33
Sanders, Thomas;Reardon, Patrick;Levy, Bruce;Krych, Aaron;Sanders, Thomas L.;Levy, Bruce A.;Krych, Aaron J.;	2017	Arthroscopic treatment of global pincer-type femoroacetabular impingement
Sochacki, K. R.;Jack, R. A., 2nd;Bekhradi, A.;Delgado, D.;McCulloch, P. C.;Harris, J. D.;	2018	Are Self-Reported Medication Allergies Associated With Worse Hip Outcome Scores Prior to Hip Arthroscopy?
Thier, S.;Baumann, F.;Weiss, C.;Fickert, S.;	2017	Feasibility of arthroscopic autologous chondrocyte implantation in the hip using an injectable hydrogel
Thier, S.;Weiss, C.;Fickert, S.;	2017	Arthroscopic autologous chondrocyte implantation in the hip for the treatment of full-thickness cartilage defects - A case series of 29 patients and review of the literature
Zingg, P. O.;Ulbrich, E. J.;Buehler, T. C.;Kalberer, F.;Poutawera, V. R.;Dora, C.;	2013	Surgical hip dislocation versus hip arthroscopy for femoroacetabular impingement: Clinical and morphological short-term results
Non-English text		
Bohnsack, M.;Lekkos, K.;Börner, C. E.;Wirth, C. J.;Rühmann, O.;	2006	Results of hip arthroscopy in sports related groin pain
Funakoshi, N.;Yamashita, F.;Nagaoka, T.;Mori, D.;	2011	Surgical Treatment of Acetabular Labral Tears in Athletes
No comparative pre/post scores		
Botser, I. B.;Jackson, T. J.;Smith, T. W.;Leonard, J. P.;Stake, C. E.;Domb, B. G.;	2014	Open surgical dislocation versus arthroscopic treatment of femoroacetabular impingement

Briggs, Karen K.;Soares, Eduardo;Bhatia, Sanjeev;Philippon, Marc J.;	2019	Postoperative alpha angle not associated with patient-centered midterm outcomes following hip arthroscopy for FAI
Briggs, Karen K;Soares, Eduardo;Bhatia, Sanjeev;Philippon, Marc J;	2018	Postoperative alpha angle not associated with patient-centered midterm outcomes following hip arthroscopy for FAI
Bryan, Andrew J.;Krych, Aaron J.;Pareek, Ayoosh;Reardon, Patrick J.;Berardelli, Rebecca;Levy, Bruce A.;	2016	Are Short-term Outcomes of Hip Arthroscopy in Patients 55 Years and Older Inferior to Those in Younger Patients?
Filbay, S. R.;Kemp, J. L.;Ackerman, I. N.;Crossley, K. M.;	2016	Quality of life impairments after hip arthroscopy in people with hip chondropathy
Giordano, B. D.;Suarez-Ahedo, C.;Gui, C.;Darwish, N.;Lodhia, P.;Domb, B. G.;	2018	Clinical outcomes of patients with symptomatic acetabular rim fractures after arthroscopic FAI treatment
Ishoi, L.;Thorborg, K.;Kraemer, O.;Lund, B.;Mygind-Klavsen, B.;Holmich, P.;	2019	Demographic and Radiographic Factors Associated With Intra-articular Hip Cartilage Injury: A Cross-sectional Study of 1511 Hip Arthroscopy Procedures
Kivlan, B. R.;Nho, S. J.;Christoforetti, J. J.;Ellis, T. J.;Matsuda, D. K.;Salvo, J. P., Jr.;Wolff, A. B.;Van Thiel, G. S.;Stubbs, A. J.;Carreira, D. S.;	2017	Multicenter Outcomes After Hip Arthroscopy: Epidemiology (MASH Study Group). What Are We Seeing in the Office, and Who Are We Choosing to Treat?
Krych, Aaron J.;King, Alexander H.;Berardelli, Rebecca L.;Sousa, Paul L.;Levy, Bruce A.;	2016	Is Subchondral Acetabular Edema or Cystic Change on MRI a Contraindication for Hip Arthroscopy in Patients With Femoroacetabular Impingement?
Krych, Aaron;Kuzma, Scott;Kovachevich, Rudy;Hudgens, Joshua;Stuart, Michael;Levy, Bruce;	2014	Modest mid-term outcomes after isolated arthroscopic debridement of acetabular labral tears
Maldonado, David R;Krych, Aaron J;Levy, Bruce A;Hartigan, David E;Laseter, Joseph R;Domb, Benjamin G;	2018	Does Iliopsoas Lengthening Adversely Affect Clinical Outcomes After Hip Arthroscopy? A Multicenter Comparative Study
Mygind-Klavsen, B.;Gronbech Nielsen, T.;Maagaard, N.;Kraemer, O.;Holmich, P.;Winge, S.;Lund, B.;Lind, M.;	2016	Danish Hip Arthroscopy Registry: an epidemiologic and perioperative description of the first 2000 procedures
Nawabi, D. H.;Degen, R. M.;Fields, K. G.;Wentzel, C. S.;Adeoye, O.;Kelly, B. T.;	2017	Anterior Inferior Iliac Spine Morphology and Outcomes of Hip Arthroscopy in Soccer Athletes: A Comparison to Nonkicking Athletes
Palmer, A. J. R.;Ayyar Gupta, V.;Fernquest, S.;Rombach, I.;Dutton, S. J.;Mansour, R.;Wood, S.;Khanduja, V.;Pollard, T. C. B.;McCaskie, A. W.;Barker, K. L.;Andrade, Tjmd;Carr, A. J.;Beard, D. J.;Glyn-Jones, S.;	2019	Arthroscopic hip surgery compared with physiotherapy and activity modification for the treatment of symptomatic femoroacetabular impingement: multicentre randomised controlled trial
Sansone, M.;Ahlden, M.;Jonasson, P.;Thomee, C.;Sward, L.;Baranto, A.;Karlsson, J.;Thomee, R.;	2014	A Swedish hip arthroscopy registry: demographics and development
Shibata, Kotaro R.;Matsuda, Shuichi;Safran, Marc R.;	2017	Arthroscopic Hip Surgery in the Elite Athlete: Comparison of Female and Male Competitive Athletes
Sochacki, Kyle R;Brown, Lindsey;Cenkus, Kathleen;Di Stasi, Stephanie;Harris, Joshua D;Ellis, Thomas J;	2018	Preoperative Depression Is Negatively Associated With Function and Predicts Poorer Outcomes After Hip Arthroscopy for Femoroacetabular Impingement
Spiker, A. M.;Rotter, B. Z.;Chang, B.;Mintz, D. N.;Kelly, B. T.;	2018	Clinical presentation of intra-articular osteoid osteoma of the hip and preliminary outcomes after arthroscopic resection: a case series
Tjong, V. K.;Cogan, C. J.;Riederman, B. D.;Terry, M. A.;	2016	A Qualitative Assessment of Return to Sport After Hip Arthroscopy for Femoroacetabular Impingement

Westermann, R. W.;Lynch, T. S.;Jones, M. H.;Spindler, K. P.;Messner, W.;Strnad, G.;Rosneck, J.;	2017	Predictors of Hip Pain and Function in Femoroacetabular Impingement: A Prospective Cohort Analysis
White, B. J.;Patterson, J.;Herzog, M. M.;	2018	Bilateral Hip Arthroscopy: Direct Comparison of Primary Acetabular Labral Repair and Primary Acetabular Labral Reconstruction
Same cohort/subcohort and outcomes as another publication		
Ashberg, Lyall;Close, Mary R.;Perets, Itay;Chaharbakhshi, Edwin O.;Walsh, John P.;Mohr, Mitchell R.;Domb, Benjamin G.;	2019	Do Femoral Head Osteochondral Lesions Predict a Poor Outcome in Hip Arthroscopy Patients? A Matched Control Study With Minimum 5-Year Follow-Up
Byrd, JW Thomas;Bardowski, Elizabeth A;Jones, Kay S;	2018	Influence of Tönnis Grade on Outcomes of Arthroscopic Management of Symptomatic Femoroacetabular Impingement
Chaharbakhshi, E. O.;Hartigan, D. E.;Spencer, J. D.;Perets, I.;Lall, A. C.;Domb, B. G.	2019	Do Larger Acetabular Chondral Defects Portend Inferior Outcomes in Patients Undergoing Arthroscopic Acetabular Microfracture? A Matched-Controlled Study
Chandrasekaran, S.;Darwish, N.;Mu, B. H.;Rybalko, D. A.;Perets, I.;Suarez-Ahedo, C.;Chaharbakhshi, E. O.;Lall, A. C.;Domb, B. G.;	2019	Arthroscopic Reconstruction of the Irreparable Acetabular Labrum: A Match-controlled Study
Chen, A. W.;Craig, M. J.;Mu, B. H.;Go, C. C.;Ortiz-Declet, V.;Maldonado, D. R.;Domb, B. G.;	2019	Return to Basketball After Hip Arthroscopy: Minimum 2-Year Follow-up
Chen, A. W.;Craig, M. J.;Yuen, L. C.;Ortiz-Declet, V.;Maldonado, D. R.;Domb, B. G.;	2019	Five-Year Outcomes and Return to Sport of Runners Undergoing Hip Arthroscopy for Labral Tears With or Without Femoroacetabular Impingement
Domb, Benjamin G.;Battaglia, Muriel R.;Perets, Itay;Lall, Ajay C.;Chen, Austin W.;Ortiz-Declet, Victor;Maldonado, David R.;	2019	Minimum 5-Year Outcomes of Arthroscopic Hip Labral Reconstruction With Nested Matched-Pair Benchmarking Against a Labral Repair Control Group
Jackson, T. J.;Hanypsiak, B.;Stake, C. E.;Lindner, D.;El Bitar, Y. F.;Domb, B. G.;	2014	Arthroscopic labral base repair in the hip: Clinical results of a described technique
Ishoi, L.;Thorborg, K.;Kraemer, O.;Holmich, P.;	2019	The association between specific sports activities and sport performance following hip arthroscopy for femoroacetabular impingement syndrome: A secondary analysis of a cross-sectional cohort study including 184 athletes
Lall, Ajay C.;Hammarstedt, Jon E.;Gupta, Asheesh G.;Laseter, Joseph R.;Mohr, Mitchell R.;Perets, Itay;Domb, Benjamin G.;	2019	Effect of Cigarette Smoking on Patient-Reported Outcomes in Hip Arthroscopic Surgery: A Matched-Pair Controlled Study With a Minimum 2-Year Follow-up
Lansdown, Drew A;Ukwuani, Gift;Kuhns, Benjamin;Harris, Joshua D;Nho, Shane J;	2018	Self-reported Mental Disorders Negatively Influence Surgical Outcomes After Arthroscopic Treatment of Femoroacetabular Impingement
Lund, B.;Nielsen, T. G.;Lind, M.;	2017	Cartilage status in FAI patients - results from the Danish Hip Arthroscopy Registry (DHAR)
Maldonado, David R.;Lall, Ajay C.;Laseter, Joseph R.;Kyin, Cynthia;Chen, Jeffrey W.;Go, Cammille C.;Domb, Benjamin G.;	2019	Primary Hip Arthroscopic Surgery With Labral Reconstruction: Is There a Difference Between an Autograft and Allograft?
Maldonado, David R.;Laseter, Joseph R.;Perets, Itay;Ortiz-Declet, Victor;Chen, Austin W.;Lall, Ajay C.;Domb, Benjamin G.;	2019	The Effect of Complete Tearing of the Ligamentum Teres in Patients Undergoing Primary Hip Arthroscopy for Femoroacetabular Impingement and Labral Tears: A Match-Controlled Study
Mygind-Klavsen, Bjarne;Lund, Bent;Nielsen, Torsten Grønbech;Maagaard, Niels;Kraemer, Otto;Hölmich, Per;Winge, Søren;Lind, Martin;	2018	Danish Hip Arthroscopy Registry: predictors of outcome in patients with femoroacetabular impingement (FAI)

Perets, Itay;Chaharbakhshi, Edwin O.;Mansor, Yosif;Ashberg, Lyall J.;Mu, Brian H.;Battaglia, Muriel R.;Lall, Ajay C.;Domb, Benjamin G.;	2019	Midterm Outcomes of Iliopsoas Fractional Lengthening for Internal Snapping as a Part of Hip Arthroscopy for Femoroacetabular Impingement and Labral Tear: A Matched Control Study
Rosinsky, P. J.;Kyin, C.;Lall, A. C.;Shapira, J.;Maldonado, D. R.;Domb, B. G.;	2019	Rate of Return to Sport and Functional Outcomes After Bilateral Hip Arthroscopy in High-Level Athletes
Tahoun, M.;Shehata, T. A.;Ormazabal, I.;Mas, J.;Sanz, J.;Tey Pons, M.;	2017	Results of arthroscopic treatment of chondral delamination in femoroacetabular impingement with bone marrow stimulation and BST-CarGel
Abstract/proceedings only		
Chahal, J.;Thiel, G. S. V.;Mather, R. C.;Lee, S.;Salata, M. J.;Nho, S. J.;	2014	The Minimal Clinical Important Difference (MCID) And Patient Acceptable Symptomatic State (PASS) For The Modified Harris Hip Score And Hip Outcome Score Among Patients Undergoing Surgical Treatment For Femoroacetabular Impingement
Domb, B. G.;Dunne, K. F.;Martin, T.;Gui, C.;Finch, N.;Stake, C. E.;	2015	Return to sports in a general hip arthroscopy cohort: Minimum two-year follow-up
Domb, B. G.;Gupta, A.;Dunne, K. F.;Stake, C. E.;Redmond, J. M.;	2014	Microfracture Of The Hip: A Two-year Follow-up With A Matched-pair Control Group
Domb, B. G.;Stake, C. E.;Finley, Z. J.;Baise, R. A.;Botser, I.;	2013	Two-year outcome of arthroscopic capsular repair of the hip: A prospective matched-pair controlled study
Economopoulos, Kostas John;Kweon, Christopher Y.;	2019	Prospective Randomized Comparison of Capsule Management Techniques During Hip Arthroscopy...AOSSM 2019–American Orthopaedic Society for Sports Medicine Annual Meeting, July 11-14, USA, Boston, MA, USA
Frank, R. M.;Lee, S.;Grzybowski, J. S.;Cvetanovich, G.;Mather, R. C.;Bush-Joseph, C. A.;Salata, M. J.;Nho, S. J.;	2015	Outcomes for hip arthroscopy based on sex and age: A comparative matched-group analysis
Harris, J. D.;	2019	In Symptomatic Femoroacetabular Impingement, Arthroscopic Hip Surgery Improved Outcomes at 8 Months Compared with Physiotherapy and Activity Modification
Jackson, T. J.;Stake, C. E.;El Bitar, Y.;Lindner, D.;Botser, I.;Domb, B. G.;	2013	Surgical dislocation of the hip versus arthroscopic treatment of femoro-acetabular impingment: A prospective comparative study with 2-year follow-up
Krych, A. J.;King, A. H.;Berardelli, R. L.;Sousa, P. L.;Levy, B. A.;	2015	Is MRI subchondral acetabular edema or cystic change a contraindication for hip arthroscopy in patients with FAI?
Lindner, D.;Stake, C. E.;Jackson, T. J.;El Bitar, Y.;Chen, A.;Domb, B. G.;	2013	Two year follow-up of hip arthroscopies: A match-controlled study comparing patients over 50 years to under 30 years
Lodhia, P.;Martin, T.;Gui, C.;Stake, C. E.;Vemula, S. P.;Suarez-Ahedo, C.;Chandrasekaran, S.;Domb, B. G.;	2015	Outcomes of 1038 hip arthroscopies: A two-year follow-up study
Nawabi, D. H.;Bedi, A.;Ranawat, A. S.;Kelly, B. T.;	2015	Outcomes of hip arthroscopy for patients with symptomatic borderline dysplasia: A comparison to a matched cohort of patients with symptomatic FAI
Redmond, J. M.;Schwartz, A. R.;Gupta, A.;Stake, C. E.;Finch, N.;Domb, B. G.;	2015	A matched-pair controlled study of arthroscopic psoas tenotomy with minimum 2-year follow-up: Do patients with psoas tenotomy achieve similar outomes?
Thorey, F.;Malahias, M. A.;Giotis, D.;	2019	Sustained benefit of autologous matrix-induced chondrogenesis for hip cartilage repair in a recreational athletic population
Greater than 10% of cohort with dysplasia or other pathologies		
Cooper, Anthony Philip;Basheer, Sheba Z.;Maheshwari, Rajan;Regan, Laura;Madan, Sanjeev S.;	2013	Outcomes of hip arthroscopy. A prospective analysis and comparison between patients under 25 and over 25 years of age
Larson, C. M.;Pierce, B. R.;Giveans, M. R.;	2011	Treatment of athletes with symptomatic intra-articular hip pathology and athletic pubalgia/sports hernia: A case series

Lee, S.;Cvetanovich, G. L.;Mascarenhas, R.;Wuerz, T. H.;Mather, R. C.;Bush-Joseph, C. A.;Nho, S. J.;	2017	Ability to return to work without restrictions in workers compensation patients undergoing hip arthroscopy
Polesello, G. C.;Keiske Ono, N.;Bellan, D. G.;Honda, E. K.;Guimaraes, R. P.;Junior, W. R.;Do Val Sella, G.;	2009	HIP ARTHROSCOPY IN ATHLETES
Uchida, S.;Hatakeyama, A.;Kanezaki, S.;Utsunomiya, H.;Suzuki, H.;Mori, T.;Chang, A.;Matsuda, D. K.;Sakai, A.;	2017	Endoscopic shelf acetabuloplasty can improve clinical outcomes and achieve return to sports-related activity in active patients with hip dysplasia
Degen, R. M.;Mayer, S. W.;Fields, K. G.;Coleman, S. H.;Kelly, B. T.;Nawabi, D. H.;	2017	Functional Outcomes and Cam Recurrence After Arthroscopic Treatment of Femoroacetabular Impingement in Adolescents
Fabricant, P. D.;Heyworth, B. E.;Kelly, B. T.;Fabricant, Peter D.;Heyworth, Benton E.;Kelly, Bryan T.;	2012	Hip arthroscopy improves symptoms associated with FAI in selected adolescent athletes
Mohan, R.;Johnson, N. R.;Hevesi, M.;Gibbs, C. M.;Levy, B. A.;Krych, A. J.;	2017	Return to Sport and Clinical Outcomes After Hip Arthroscopic Labral Repair in Young Amateur Athletes: Minimum 2-Year Follow-Up
Wylie, J. D.;Beckmann, J. T.;Maak, T. G.;Aoki, S. K.;	2015	Arthroscopic treatment of mild to moderate deformity after slipped capital femoral epiphysis: intra-operative findings and functional outcomes
Greater than 10% of the cohort undergoing revision surgery		
Boykin, Robert E.;Patterson, Diana;Briggs, Karen K.;Dee, Ashley;Philippon, Marc J.;	2013	Results of Arthroscopic Labral Reconstruction of the Hip in Elite Athletes
Domb, Benjamin G.;El Bitar, Youssef F.;Stake, Christine E.;Trenga, Anthony P.;Jackson, Timothy J.;Lindner, Dror;	2014	Arthroscopic Labral Reconstruction Is Superior to Segmental Resection for Irreparable Labral Tears in the Hip: A Matched-Pair Controlled Study With Minimum 2-Year Follow-up
Domb, Benjamin G;Martin, Timothy J;Gui, Chengcheng;Chandrasekaran, Sivashankar;Suarez-Ahedo, Carlos;Lodhia, Parth;	2018	Predictors of Clinical Outcomes After Hip Arthroscopy: A Prospective Analysis of 1038 Patients With 2-Year Follow-up
Hartigan, David E;Perets, Itay;Close, Mary R;Walsh, John P;Chaharbakhshi, Edwin O;Mohr, Mitchell R;Domb, Benjamin G;	2018	Arthroscopic Treatment of Iliopsoas Snapping in Patients With Radiographic Acetabular Dysplasia Using Iliopsoas Fractional Lengthening and Capsular Plication
Locks, Renato;Utsunomiya, Hajime;Briggs, Karen K.;McNamara, Shannen;Chahla, Jorge;Philippon, Marc J.;	2018	Return to Play After Hip Arthroscopic Surgery for Femoroacetabular Impingement in Professional Soccer Players
Philippon, Marc J;Bolia, Ioanna K;Locks, Renato;Briggs, Karen K;	2018	Labral Preservation: Outcomes Following Labrum Augmentation Versus Labrum Reconstruction
Philippon, Marc;Schenker, Mara;Briggs, Karen;Kuppersmith, David;	2007	Femoroacetabular impingement in 45 professional athletes: associated pathologies and return to sport following arthroscopic decompression
Thomas, Darren D.;Bernhardson, Andrew S.;Bernstein, Ethan;Dewing, Christopher B.;	2017	Hip Arthroscopy for Femoroacetabular Impingement in a Military Population
White, B. J.;Stapleford, A. B.;Hawkes, T. K.;Finger, M. J.;Herzog, M. M.;	2016	Allograft use in arthroscopic labral reconstruction of the hip with front-to-back fixation technique: Minimum 2-year follow-up
Mixed arthroscopic and open Surgery		
Fitzgerald Jr, R. H.;	1995	Acetabular labrum tears: Diagnosis and treatment
Mannion, A. F.;Impellizzeri, F. M.;Naal, F. D.;Leunig, M.;	2013	Fulfilment of patient-rated expectations predicts the outcome of surgery for femoroacetabular impingement

Additional file 4 – Characteristics and outcomes of included studies

Additional file 4- Characteristics and outcomes of included studies

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Randomised Controlled Trials													
Bennell et al. [131]	14/11 Group 1 [PT rehab]	14%(2)	31±7	FAI/FAIS	Elite/sub-elite (international /national) 36%(5); State 50%(7); Recreational 13%(2); Never competed (0)	NR	HOS-SS	24 wk	≤ 6	50.9±17.1	85.0±17.8	-1.89[-2.87 to -0.92]	
	16/11 Group 2 [no PT rehab]	25%(2)	29±8	FAI/FAIS	Elite/sub-elite (international /national) 38%(6); State 19%(3); Recreational 31%(5); Never competed 13%(2)	NR	HOS-SS	24 wk	≤ 6	52.1±16.7	86±12.4	-2.17[-3.16 to -1.18]	
	Group 1						HAGOS-SR	24 wk	≤ 6	35.9±16.9	81.5±23.4	-2.21[-3.24 to -1.17]	
	Group 2						HAGOS-SR	24 wk	≤ 6	43.9±19.3	78.4±18.6	-1.76[-2.68 to -0.84]	
	Group 1						Tegner	24 wk	≤ 6	3.9±1.8	5.5±1.6	-0.90[-1.74 to -0.07]	
	Group 2						Tegner	24 wk	≤ 6	4.3±2.2	5.6±1.6	-0.64[-1.43 to 0.15]	
	Group 1						HSAS	24 wk	≤ 6	31.0±18.0	31.0±8.5	0.00[-0.79 to 0.79]	
	Group 2						HSAS	24 wk	≤ 6	31.9±21.6	34.4±17.5	-0.12[-0.89 to 0.65]	
Mansell et al. [100]	66/66 [Surgical only]	41%(27)	30±7	FAI/FAIS	NR	NR	HOS-SS	2 yr	19-24	52.6±17.0	57.3±27.5	-0.21[-0.55 to 0.13]	
Prospective Studies, more than 1 arm (Only groups meeting criteria reported)													
Chaharbakhshi et al [43]	20/20 Group 1 [Lig Teres tear]	90%(18)	30±12	Borderline dysplasia; Lig Teres tear	NR	NR	HOS-SS	54.3±17.3 mo	≥ 25	44.1±22.8	68.1±28.9	-0.90[-1.56 to -0.25]	
	20/20 Group 2 [No tear]	90%(18)	27±12	Boarderline dysplasia	NR	NR	HOS-SS	38.6±13.7 mo	≥ 25	50.4±23.9	75.6±19.6	-1.13[-1.80 to -0.46]	
Domb et al. [58]	62/62 HIPS Group 1	60%(37)	42±12	FAI/FAIS; Labral tear	NR	NR	HOS-SS	69.3±7.8 mo	≥ 25	46.7±22.8	73.6±26.9	-1.07[-1.45 to -0.69]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
	[Tönnis grade 1]												
	62/62 HIPS Group 2 [Tönnis grade 0]	60%(37)	42±12	FAI/FAIS	NR	NR	HOS-SS	72.1±7.9 mo	≥ 25	46.4±24.7	78.2±17.8	-1.47[-1.87 to -1.07]	
Flores et al. [69]	30/30 HIPS Group1 [Early career]	50%(15)	37±11.5	FAI/FAIS	NR	NR	HOOS-SR	15.5±4.7 mo	13 to 18	36.3±27.2	65.2±27.0	-1.05[-1.59 to -0.51]	
	30/30 HIPS Group2 [Late career]	43%(13)	35±11	FAI/FAIS	NR	NR	HOOS-SR	13.1±2.7 mo	13 to 18	44.5±25.2	75.6±28.9	-1.13[-1.68 to -0.58]	
Flores et al. [70]	39/39 HIPS Group 1 [Retro-version]	59%(23)	31±11	FAI/FAIS; Acetabular retro-version	NR	NR	HOOS-SR	1 yr	7 to 12	38.9±22.1	78.7±16.6	-2.02[-2.57 to -1.47]	
	39/39 HIPS Group 2 [Pincer]	59%(23)	34±8	FAI/FAIS; Focal pincer	NR	NR	HOOS-SR	1 yr	7 to 12	41.9±25.5	77.9±22.9	-1.47[-1.97 to -0.97]	
Glaws et al. [76]	42/28	54%(15)	25±10	FAI/FAIS	Professional; Recreational; High school; College	NR	HOS-SS	6 mo	≤ 6	50.8±21.7	74.8±22.7	-1.07[-1.63 to -0.50]	
Kemp et al. [89]	100/66	49%(49)	36±10	FAI/FAIS +/- Chondropathy	NR	NR	HOOS-SR	30 mo	≥ 25	72.5±23.6	74.9±26.2	-0.10[-0.44 to -0.24]	
Kierkegaard et al.[154]	60/41	63%(38)	36±9	FAI/FAIS	NR	NR	HAGOS-SR	1 yr	7 to 12	*(Median IQR) 31 (20; 48)*	*59 (41; 78)*		Statistically significant change (P <0.001)
							HAGOS-PA	1 yr	7 to 12	*13(0; 31)*	*25 (13; 56)*		Statistically significant change (P <0.001)
							Self-reported PA hr/week	1 yr	7 to 12	*1 (0; 4)*	*4.0 (2; 6)*		Level of significance not reported

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
							Accelerometer data examples						
							% high activity	1 yr	7 to 12	*4.0 (2; 6)*	*4 (3; 5)*		All activity metrics identified as no significant change.
							Steps running	1 yr	7 to 12	*7 (0; 63)*	*23 (0; 108)*		
							Bicycling rotations	1 yr	7 to 12	*45 (8; 434)*	*123 (11; 762)*		
Krych et al. [91]	18/18 Group 1 [Repair]	100%(18)	38(20-59)	FAI/FAIS; Labral tear	NR	NR	HOS-SS	32(12-48) mo	≥ 25	47.5±NR	88.7±NR		
	18/18 Group 2 [Debridement]	100%(18)	39(19-55)	FAI/FAIS; Labral tear	NR	NR	HOS-SS	32(12-48) mo	≥ 25	40.6±NR	76.3±NR		
Newman et al. [104]	492/492 [Primary surgery]	59%(290)	32±10	Non specified	NR	NR	HOS-SS	2 yr (min)	19 to 24	48.0±24.0	77.1±26.0	-1.16[-1.30 to -1.03]	
Redmond et al. [113]	85/85 HIPS Group 1 [No labral detachment]	71%(60)	33±13	FAI/FAIS; Labral tear	NR	NR	HOS-SS	2 yr	19 to 24	45.0±26.1	75.1±28.0	-1.11[-1.43 to -0.78]	
	105/105 HIPS Group 2 [Labral detachment]	57%(60)	33±12	FAI/FAIS; Labral tear	NR	NR	HOS-SS	2 yr	19 to 24	40.1±23.3	74.1±25.4	-1.39[-1.69 to -1.09]	
Redmond et al. [114]	104/91 Group 1 [+PRP]	70%(73)	36±NR	Labral tear	NR	NR	HOS-SS	2 yr (min)	19 to 24	41.3± NR	67.5±NR		Statistically significant change (P <0.05), both groups.
	202/180 Group 2 [No PRP]	64%(130)	36.5	Labral tear	NR	NR	HOS-SS	2 yr (min)	19 to 24	43.5± NR	69.1±NR		
Thorborg et al. [18]	97/76	58% (56)	37(19-59)	FAI/FAIS +/- Labral tear	NR	NR	HAGOS SR (unadjust	12 mo	7 to 12	39.0±19.7	70.5±23.8	-1.45[-1.79 to -1.11]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
							ed scores)						
							HAGOS PA (unadjusted scores)	12 mo	7 to 12	19.8±24.2	54.9±37.3	-1.14[-1.47 to -0.82]	
Zimmerer et al. [130]	20/NR Group 1 [Sitting]	28% (12)	25(19-30)	FAI/FAIS	Work activity -sitting	NR	HOOS-SR	24(18-32) mo [Whole cohort]	19 to 24 [Whole cohort]	45.6± NR	80.0±NR		Statistically significant change for group 1 (p=<0.001) and group 2 (p=0.004). Change not statistically significant for group 3 (p=0.186)
	13/NR Group 2 [Standing]				Work activity - standing	NR				36.1± NR	59.6±NR		
	10/NR Group 3 [Active]				Work activity - physical	NR				34.8± NR	57.1±NR		
Prospective Studies, single arm													
Bennett et al. [42]	101/97	26%(26)	33(20-50)	FAI/FAIS	Military personnel	NR	FAA	1 yr	7 to 12	2.8±1.0	2.2±1.1	0.57[0.28 to 0.86]	
Chahal et al [37]	130/130	58%(75)	36±12	FAI/FAIS	NR	NR	HOS-SS	2 yr	8 to 12	43.2±26.2	75.4±19.7	-1.39[-1.66 to -1.11]	
Davis et al. [53]	42/28	54%(15)	26±10	FAI/FAIS	Participants in cutting, jumping, pivoting, or lateral movement activities for at least 50 hours per year prior to the onset of hip symptoms	NR	HOS-SS	180 ±32 days	≤ 6	50.8±21.7	74.7±21.8	-1.09[-1.60 to -0.57]	
Domb et al. [63]	43/43 HIPS	35%(15)	44±10	Acetabular chondral defects	NR	NR	HOS-SS	67.6±8.2 mo	≥ 25	40.2±23.2	62.3±30.5	-0.81[-1.25 to -0.37]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Ishoi et al [17]	189/108 [HAGOS scores]	49%(93)	24±3	FAI/FAIS	Mixed levels athlete (elite, competitive, recreational); Whole cohort 'actively involved in sport'	Contact; Noncontact + pivoting; Noncontact + nonpivoting	HAGOS-SR	33.1±16.3 mo	≥ 25	43.4±24.0	61.1±29.5	-0.66[-0.93 to -0.38]	
							HAGOS-PA	33.1±16.3 mo	≥ 25	21.2±25.1	48.7±27.5	-1.04[-1.33 to -0.76]	
Öhlin et al.[150]	361/184	40%(74)	38±13	FAI/FAIS	NR	NR	HAGOS-SR	60 mo	≥ 25	41.1±22.1	66.4±29.9	-0.96 [-1.18 to -0.74]	
							HAGOS-PA	60 mo	≥ 25	30.8±28.2	60.2±33.1	-0.95 [-1.17 to-0.74]	
Philippon [132]	112/90		41	FAI/FAIS	NR	NR	HOS-SS	2.3(2.0-2.9) yr	≥ 25	43.0±NR	69.0±NR		Change HOS-SS = -24 (95% CI -32 to -16)
Sansone et al. [118]	85/85	55%(62)	25±5	FAI/FAIS	Elite Sub elite National International	Cutting (79%); Flexibility; Contact; Impingement; Asymmetric /overhead; Endurance	HAGOS-SR	12.3±0.6 mo	7 to 12	39.0±21.0	75.0±23.0	-1.63[-1.98 to -1.28]	
							HAGOS-PA	12.3±0.6 mo	7 to 12	27.0±28.0	70.0±30.0	-1.48[-1.82 to -1.14]	
							HSAS			4.3±2.5	5.7±2.2	-0.63[-0.94 to 0.33]	
Sansone et al.[6]	394/289	34%(134)	37±13	FAI/FAIS	NR	NR	HAGOS-SR	25±2 mo	≥ 25	40.0±20.0	65.0±29.0	-1.00[-1.18 to -0.83]	
							HAGOS-PA	25±2 mo	≥ 25	29.0±26.0	57.0±34.0	-0.92[-1.10 to -0.75]	
							HSAS			2.9±2.2	3.6±2.1	-0.33[-0.49 to -0.16]	
Tahoun et al. [123]	23/23	22%(5)	41±7	FAI/FAIS; Chondral defect	Tegner 6±1.5 [range 3 to 10]	NR	HOS-SS	38.4±7 mo	≥ 25	30.9±13.9	70.8±26.2	-1.87[-2.57 to -1.17]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Tijssen et al. [124]	45/37	43%(16)	40.5±9	Not specified	Recreational	Cutting (19%); Endurance (30%); Other (38%); No sport (13%)	iHot – 33 SR	26.8±11.6 mo	≥ 25	NR±NR	60.5±27.5		Statistically significant decrease in sport frequency (p=0.04) **pre-injury** to post-op.
							Tegner			NR±NR	6.2±1.9		
Retrospective Studies, more than 1 arm (Only groups meeting criteria reported)													
Basques et al.[133]	707/624	65%(406)	34±14	FAI/FAIS	"Regular exercise" – not defined 71.6% of cohort	NR	HOS-SS	2 yr	19 to 24	44.9±22.8	71.3±27.1	-1.05 [-1.17 to -0.94]	
Beck et al.[135]	112/112	72%(81)	34 ±13	FAI/FAIS	NR	NR	HOS-SS	32.9±9.3 mo	≥25	41.7±20.5	72.6±27.1	-1.28 [-1.57 to -0.99]	
	224/224 Group 2 [	68%(153)	34± 13	FAI/FAIS	NR	NR	HOS-SS	32.9±9.3 mo	≥25	43.9±22.8	74.7±26.1	-1.25 [-1.46 to -1.05]	
Bolia et al [136]	42/42 Group 1 [no capsular repair]	43%(18)	38±15	FAI/FAIS, Labral tear	NR	NR	HOS-SS	7.3±2.7 yr	≥25	43±25	74±24	-1.25 [-1.72 to -0.78]	
	84/84 Group 2 [capsular repair]	43%(36)	38±15	FAI/FAIS, Labral tear	NR	NR	HOS-SS	6.4±2.3 yr	≥25	48±24	79±21	-1.37 [-1.71 to -1.03]	
Cancienne et al [137]	120/120	61%(73)	37±6	FAI/FAIS	NR	NR	HOS-SS	33.7±3.1 mo	≥25	46±24.2	74.7±22.2	-1.23 [-1.51 to -0.96]	
Chaharbakhshi et al[138]	16/12 Group 1[anteversion and dysplasia]	100%(12)	29±13	Borderline dysplasia	NR	NR	HOS-SS	44.2±23.4 mo	≥25	34.9±23.9	58.3±37.5	-0.72 [-1.55 to 0.11]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
	24/24 Group 2 [Control]	100%(24)	28±13	Not specified	NR	NR	HOS-SS	44.2±16.5 mo	≥25	46.1±23.4	78.4±22	-1.40 [-2.04 to -0.76]	
Chahla et al [140]	267/267 Group1 [small tear]	82%(218)	32±12	FAI/FAIS, Labral tear	'Runners'	Endurance	HOS-SS	2 yr	19 to 24	41.6±22.3	76.6±23.5	-1.53 [-1.72 to -1.33]	
	333/333 [large tear]	51%(169)	35±12	FAI/FAIS, Labral tear	'Runners'	Endurance	HOS-SS	2 yr	19 to 24	42.6±22.9	70.5±27.7	-1.10 [-1.26 to -0.93]	
Chandrasekaran et al. [49]	12/10 HIPS Group 1 [Lower index score]	58%(7)	45±8	Labral tear +/- FAI/FAIS	NR	NR	HOS-SS	2 yr	19 to 24	41.8±NR	45.3±NR		No statistically significant change in scores group 1 (p=0.788). Statistically significant change group 2 (p<0.001)
	52/42 HIPS Group 2 [Higher index score]	85%(44)	41±13	Labral tear +/- FAI/FAIS	NR	NR	HOS-SS	2 yr	19 to 24	36.3±NR	67.9±NR		
Chandrasekaran et al. [47]	93/93 Group 1 [Tönnis 1]	48%(45)	41(16-64)	Mild OA (Tönnis grade 1)	NR	NR	HOS-SS	28(23-67.9) mo	≥ 25	40.2±NR	60.9±NR		Statistically significant change for both groups (p<0.001)
	93/93 Group 2 [Tönnis 0]	48%(45)	41(15-63)	Tönnis grade 0	NR	NR	HOS-SS	31.5(23.6-63.5) mo	≥ 25	39.7±NR	61.3±NR		
Chandrasekaran et al. [44]	36/36 Group1 [Over-coverage]	50%(18)	31(16-50)	Labral tear; Acetabular over-coverage	NR	NR	HOS-SS	31.5(21.3-46.2) mo	≥ 25	46.0±26.5	63.2±33.0	-0.57[-1.04 to -0.10]	
	36/36 Group2 [Normal coverage]	50%(18)	32(16-33)	Labral tear; Normal acetabular coverage	NR	NR	HOS-SS	29.3(20.7-46.9) mo	≥ 25	40.5±24.6	69.0±32.0	-0.99[-1.48 to -0.50]	
Chandrasekaran et al [142]	57/57 Group 1 [Lumbar surgery]	56%(32)	46(21-69)	Not specified	NR	NR	HOS-SS	27.6±NR mo	≥ 25	22.8±21.8	50.6±31.5	-1.02 [-1.41 to -0.63]	
	57/57 Group 2 [Control]	56%(32)	46(23-73)	Not specified	NR	NR	HOS-SS	28.5±NR mo	≥ 25	38.1±27	60.9±32.8	-0.75 [-1.13 to -0.37]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Chen et al. [50]	101/69 HIPS Group 1 (SDLP)	74%(75)	44±15	Labral tear	NR	NR	HOS-SS	66.5±8 mo	≥ 25	57.4±19.6	83.6±17.2	-1.41[-1.79 to -1.04]	
Clapp et al [143]	59/59 Group 1 [Athletes]	61%(37)	23±5	FAI/FAIS	Competitive	Cutting (32%); Flexibility (12%); Contact (3%); Asymmetric /overhead (31%); Endurance (10%)	HOS-SS	2 yr	19 to 24	45.7±18.2	84.5±19	-2.07 [-2.52 to -1.62]	
	118/118 Group 2 [Non athletes]	73%(85)	24±3	FAI/FAIS	Non-competitive	NR	HOS-SS	2 yr	19 to 24	41.3±20.7	76.1±23.8	-1.56 [-1.85 to -1.26]	
Cvetanovich et al [51]	36/36 Group 1 [Boarderline dysplasia]	75%(27)	32±12	FAI/FAIS; Borderline dysplasia	NR	Endurance (58%)	HOS-SS	2.6±0.6 yr	≥ 25	44.5±20.9	73.6±26.7	-1.20[-1.70 to -0.70]	
	312/312 Group 2 [Normal coverage]	57%(177)	33±12	FAI/FAIS	NR	Endurance (60%)	HOS-SS	2.6±0.6 yr	≥ 25 mo	42.8±23.3	73.1±27.1	-1.20[-1.37 to -1.03]	
Degen et al. [55]	12/12 Group 1 [Simultaneous bilateral]	42%(5)	21±5	FAI/FAIS	NR	NR	HOS-SS	16.4 mo	13 to 18	62.7±21.7	93.3±10.2	-1.74[-2.71 to -0.78]	
	24/24 Group 2 [Staged bilateral]	42%(10)	21±5	FAI/FAIS	NR	NR	HOS-SS	17.8 mo	13 to 18	54.3±22.2	83.9±20.5	-1.36[-2.00 to -0.73]	
Domb et al. [64]	20/20 [Arhtroscopic]	80%(16)	20	FAI/FAIS	NR	NR	HOS-SS	25.5 mo	≥ 25	44.3±NR	87.1±12.1		
Domb et al. [60]	21/21 Group1 [Non-workcover]	40%(12) [whole cohort]	45	Labral tear; Full thickness cartilage defect	NR	NR	HOS-SS	35(24-50) mo	≥ 25	38.1±NR	69.5±NR		Statistically significant change in both groups ($p<0.05$).

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
	9/9 Group 2 [Workcover]			Labral tear; Full-thickness cartilage defect	NR	NR	HOS-SS	35(24-50) mo	≥ 25	22.9±NR	54.0±NR		
Domb et al. [62]	52/52 [≤30]	65%(34)	20(13-30)	Not specified	NR	NR	HOS-SS	2.7 yr	≥ 25	42.2±NR	72.7±NR		Statistically significant change (P<0.001).
Domb et al. [65]	235/235 Group 1 [Release]	41%(97)	42±12	Intra-articular	NR	NR	HOS-SS	2.2±0.4 yr	≥ 25	36.9±26.2	67.3±29.4	-1.09[-1.28 to -0.89]	
	168/168 Group 2 [Repair]	81%(136)	29±12	Intra-articular	NR	NR	HOS-SS	2.1±0.3 yr	≥ 25	46.4±23.6	71.3±27.7	-0.96[-1.19 to -0.74]	
Domb et al. [59]	88/88 Group 1 [Returned to sport]	63%(67) [HIPS]	31(13-61)	Not specified	Professional; Recreational; High school; College	Cutting; Contact; Impingement; Asymmetric /overhead; Endurance	HOS-SS	2 yr (min)	19 to 24	44.9± NR	76.0±NR		
	60/60 Group 2 [Not returned to sport]	53%(35) [HIPS]	30(14-59)	Not specified	Professional; Recreational; High school; College		HOS-SS	2 yr (min)	19 to 24	41.9±NR	62.0±NR		
Domb et al. [61]	926/824 HIPS Group 1 [Primary]	58%(540)	37(17-76)	Not specified	NR	NR	HOS-SS	28.8(23.5-76.3) mo	≥ 25	NR±NR	80.0±NR		Pre to post-op mean change HOS-SS = 23.8
Domb et al. [56]	65/65 Group 1 [Capsular release]	72%(47)	38±13	Labral tear	NR	NR	HOS-SS	75.7±8.6 mo	≥ 25	43.6±23.9	76.1±24.4	-1.34[-1.72 to -0.96]	
	65/65 Group 2 [Capsular closure]	72%(47)	37±12	Labral tear	NR	NR	HOS-SS	64.8±4.2 mo	≥ 25	45.0±27.7	68.1±27.4	-0.83[-1.19 to -0.47]	
Fabricant et al [68]	243/210 [Whole cohort, those completing HOS]	51%(123)	28±9	FAI/FAIS	NR	NR	HOS-SS	1 yr (min)	7 to 12	NR±NR	NR±NR		Pre to post-op change HOS-SS =23 (95%CI 19 to 27)
Frank et al. [71]	32/32 Group 1 [Partial closure]	63%(20)	33±10	FAI/FAIS	NR	NR	HOS-SS	30.1±2.9 mo	≥ 25	39.4±23.9	83.6±9.6	-2.40[-3.05 to -1.75]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
	32/32 Group 2 [Complete closure]	63%(20)	33±10	FAI/FAIS	NR	NR	HOS-SS	29.7±2.5 mo	≥ 25	39.1±24.2	87.3±8.3	-2.63[-3.31 to -1.95]	
Frank et al. [72]	75/75 Group 1 [Females]	100%(75)	38±14	FAI/FAIS	NR	NR	HOS-SS	33.64 ± 5.7 mo	≥ 25	40.6±22.1	81.2±14.9	-2.14[-2.54 to -1.74]	
	75/75 Group 2 [Males]	0%(0)	37±12	FAI/FAIS	NR	NR	HOS-SS	33.64 ± 5.7 mo	≥ 25	46.7±26.3	86.3±11.6	-1.94[-2.33 to -1.55]	
Frank et al [144]	97/97 Group 1 [Athletes]	100%(97)	36±10	FAI/FAIS	Recreational (88)%; High school (8%); Collegiate (3%); Professional (<1%)	Cutting; Flexibility; Asymmetric /overhead; Endurance	HOS-SS	2.6±1 yr	≥ 25	39.9±20.7	82.2±18.5	-2.15 [-2.50 to -1.79]	
	97/97 Group 2 [Non-athletes]	100%(97)	38±10	FAI/FAIS	Non-athletes	NR			≥ 25	32.3±24.1	49.2±34.1		
Gupta et al. [77]	87/62 Group1 [Obese]	73%(45)	42(17-61)	Not specified	NR	NR	HOS-SS	2.7 yr	≥ 25	25.4±22.3	55.5±32.4	-1.08[-1.45 to -0.70]	
	364/124 Group 2 [Control]	72%(90)	42(17-65)	Not specified	NR	NR	HOS-SS	2.5 yr	≥ 25	42.0±24.2	71.4±27.2	-1.14[-1.41 to -0.87]	
Hartigan et al. [80]	59/59 Group 1 [Retro-version]	61%(36)	36±15	Femoral retro-version	NR	NR	HOS-SS	37.6±14.9 mo	≥ 25	45.7±25.5	69.4±28.0	-0.88[-1.26 to -0.50]	
	59/59 Group 2 [Normal version]	68%(40)	36±13	Not specified	NR	NR	HOS-SS	37.9±13 mo	≥ 25	44.8±23.8	65.3±33.1	-0.71[-1.08 to -0.33]	
Hartigan et al. [79]	15/15 Group 1 [Micro-fracture]	47%(7)	45±9	Femoral head chondral damage (grade IV)	NR	NR	HOS-SS	36.8±16.3 mo	≥ 25	26.7±21.6	57.2±25.9	-1.24[-2.04 to -0.45]	
	45/45 Group 2 [No micro-fracture]	47%(21)	44±8	Not specified	NR	NR	HOS-SS	40.6±18 mo	≥ 25	42.3±26.1	66.7±28.9	-0.88[-1.31 to -0.45]	
Hassebrock et al [145]	133/133 Group 1[First hip]	65%(86)	32(29-34)	FAI/FAIS, Labral tear	NR	NR	HOS-SS	>2 yr	≥ 25	39.3±NR	70.7±NR		

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
	133/133 Group 2 [Second hip]	65%(86)	32(29-34)	FAI/FAIS, Labral tear	NR	NR	HOS-SS	>2 yr	≥ 25	38.5±NR	68.5±NR		
Hevesi et al [83]	96/96 Group 2 [Non-dysplasic	51%(49)	31±12	Labral tear	NR	NR	HOS-SS	5.7 (5.0-7.7) yr	≥ 25	41.1±25.0	71.0±26.6	-1.15[-1.46 to -0.85]	
Hevesi et al [146]	82/82 HIPS Group 1 [	46%(34)	33±11	Labral tear; Chondral damage	NR	NR	HOS-SS	4 (2-8.5) yr	≥ 25	47.1±26.1	75.5±26.4	-0.96 [-1.29 to-0.64]	
	31/31 HIPS Group 2 [	34%(11)	39±9	Labral tear; Chondral damage	NR	NR	HOS-SS	4 (2-8.5) yr	≥ 25	45.6±27.5	66.3±26.5	-0.76 [-1.27 to -0.24]	
Jackson et al. [86]	110/110 Group 1 [Labral base repair]	69%(76)	27	Labral tear	NR	NR	HOS-SS	30(19.2-60) mo	≥ 25	46.0±NR	76.0±NR		Statistically significant change in both groups (p<0.001)
	110/110 Group 2 [Circumferential suture]	69%(76)	27	Labral tear	NR	NR	HOS-SS	30(19.2-67) mo	≥ 25	45.0±NR	76.0±NR		
Jackson et al. [87]	22/22 Group 1 [Femoral retro-version]	77%(17)	38(14-55)	Not specified	NR	NR	HOS-SS	28.4±5.6 mo	≥ 25	46.9±27.4	79.2±17.9	-1.37[-2.03 to -0.71]	
	196/196 Group 2 [Normal ante-version]	62%(121)	38(14-66)	Not specified	NR	NR	HOS-SS	28.3±5.8 mo	≥ 25	42.0±24.6	69.6±28.1	-1.04[-1.25 to -0.83]	
	27/27 Group 3 [Excessive femoral ante-version]	74%(20)	38(15-69)	Not specified	NR	NR	HOS-SS	32.3±6.8 mo	≥ 25	45.8±23.3	72.9±28.7	-1.02[-1.59 to -0.45]	
Krishnamoorthy et al. [147]	21/21 Group 1 [symphysis pubis change]	65%(15)	37±13	FAI/FAIS	NR	NR	HOS-SS	2 yr	19 to 24	41.2±14.7	61.9±37.4	-0.71 [-1.34 to -0.09]	
	42/42 Group 2 [Control]	63%(29)	37±13	FAI/FAIS	NR	NR	HOS-SS	2 yr	19 to 24	46.9±13.9	91.6±14.5	-3.12 [-3.76 to -2.47]	
Kuhns et al. [92]	43/43 Group 1 [Bilateral arthroscopy]	56%(24)	29±11	FAI/FAIS	Recreational or high-level	NR	HOS-SS	2.3±0.37 yr	≥ 25	45.6±24.1	73.4±26.0	-1.10[-1.55 to -0.64]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
					amateur sports								
	86/86 Group 2 [Unilateral arthroscopy]	56%(48)	29±11	FAI/FAIS	Recreational or high-level amateur sports	NR	HOS-SS	2.6±0.66 yr	≥ 25	44.9±23.1	71.6±28.1	-1.03[-1.35 to -0.71]	
Kunze et al [148]	1094/1094	66%(721)	32±12	FAI/FAIS	NR	NR	HOS-SS	30.8±6.7 mo	≥ 25	42.5±22.6	74.6±25.5	-1.33 [-1.42 to -1.24]	
Levy et al. [94]	28/28 Group 1 [Atypical presentation]	64%(18)	36±10	FAI/FAIS	NR	NR	HOS-SS	2 yr	19 to 24	42.0±25.5	71.0±26.2	-1.11[-1.67 to -0.54]	
	56/56 Group 2 [Typical presentation]	64%(36)	35±10	FAI/FAIS	NR	NR	HOS-SS	2 yr	19 to 24	44.4±24.9	71.3±27.3	-1.02[-1.42 to -0.63]	
Locks et al. [96]	35/35 Group 2 [Control]	78%(28)	33±14	Labral tear	NR	NR	HOS-SS	3.6±1 yr	≥ 25	38.0±NR	57.0±32.0		Both groups showed significant improvement from pre- to postoperative scores' – values not reported.
Lodhia et al. [97]	35/35 Group 1 [Microfracture]	34%(12)	42(28-53)	FAI/FAIS; &/or Labral tear; Grade IV Outerbridge cartilage defect	NR	NR	HOS-SS	3 yr	≥ 25	42.1±24.2	61.4±26.1	-0.76[-1.24 to -0.27]	
	70/70 Group 2 [Control]	34%(24)	42(24-61)	FAI/FAIS; and/or Labraltear	NR	NR	HOS-SS	3 yr	≥ 25	37.6±25.1	63.7±27.9	-0.98[-1.33 to -0.62]	
Lodhia et al. [98]	49/49 Group 1 [Central acetabular decomp]	43%(21)	49(29-61)	FAI/FAIS; and/or Labral tear	NR	NR	HOS-SS	26.1(23.5-36.5) mo	≥ 25	43.9±22.6	59.1±28.1	-0.59[-1.00 to -0.19]	
	147/147 Group 2 [Control]	43%(63)	48(25-66)	FAI/FAIS; and/or Labral tear	NR	NR	HOS-SS	27.77(23.6-54.9) mo	≥ 25	38.3±24.7	62.3±28.5	-0.90[-1.14 to -0.66]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Nawabi et al. [103]	46/46 Group1 [Borderline dysplasia]	48%(22)	30±9	FAI/FAIS; Borderline dysplasia	NR	NR	HOS-SS	24 mo (min)	19 to 24	54.6±23.0	85.4±22.1	-1.35[-1.81 to -0.90]	
	131/131 Group 2 [Control]	56%(73)	30±10	FAI/FAIS	NR	NR	HOS-SS	23 mo (min)	19 to 24	53.3±23.7	78.8±25.2	-1.04[-1.30 to -0.78]	
Perets et al. [108]	60/41 Group 1 [IFL]	80%(48)	20±4	FAI/FAIS	Professional; High school; Collegiate	NR	HOS-SS	2 yr (min)	19 to 24	44.1±17.7	73.0±24.9	-1.33[-1.81 to -0.85]	
	41/41 Group 2 [Control]	NR	NR	FAI/FAIS	Professional; High school; Collegiate	NR	HOS-SS	NR	NR	NR±NR	NR±NR		
Perets et al. [110]	11/11Group 1 [Calcification]	100%(11)	40±6	FAI/FAIS; Labral tear	NR	NR	HOS-SS	45±19.9 mo	≥ 25	35.4±23.7	62.7±26.1	-1.05[-1.96 to -0.15]	
	11/11 Group 2 [Control]	100%(11)	40±6	FAI/FAIS; Labral tear	NR	NR	HOS-SS	49.8±22.4 mo	≥ 25	45.8±21.5	70.2±24.9	-1.01[-1.91 to -0.11]	
Perets et al. [107]	74/74 Group 1 [Obese BMI ≥30]	61%(45)	44±12	FAI/FAIS; Labral tear	NR	NR	HOS-SS	71.6±10.6 mo	≥ 25	25.2±21.3	62.9±30.8	-1.42[-1.78 to -1.06]	
	74/74 Group 2 [BMI 18.5 to 24.99	61%(45)	44±12	FAI/FAIS; Labral tear	NR	NR	HOS-SS	71.3±9.5 mo	≥ 25	37.7±26.5	70.0±24.7	-1.25[-1.61 to -0.90]	
Saltzman et al. [117]	NR/197 Group 1 [Normal weight]	72%(142)	30±11	FAI/FAIS	78% 'sport activity' - unspecified	NR	HOS-SS	2.6±0.5 yr	≥ 25	43.6±23.2	76.6±24.8	-1.37[-1.59 to 1.15]	
	NR/130 Group 2 [Over-weight]	43%(56)	35±12	FAI/FAIS	69% 'sport activity' - unspecified	NR	HOS-SS	2.6±0.5 yr	≥ 25	43.3±24.7	68.7±29.4	-0.93[-1.19 to -0.68]	
Sawyer et al. [119]	189/189 Group 1 [Looped]	48%(91)	36±11	FAI/FAIS;Labral & chondral damage	NR	NR	HOS-SS	39.6±10.4 mo	≥ 25	50.6±25.3	81.0±20.8	-1.31[-1.53 to -1.09]	
	60/60 Group 2 [Pierced]	48%(29)	36±11	FAI/FAIS; Labral & chondral damage	NR	NR	HOS-SS	36.8±8.9 mo	≥ 25	46.4±22.6	77.1±26.6	-1.24[-1.63 to -0.84]	
	77/77 Group 3 [Combined]	57%(44)	33±11	FAI/FAIS; Labral &	NR	NR	HOS-SS	32.7±7.4 mo	≥ 25	52.4±21.4	79.1±23.5	-1.18[-1.53 to -0.84]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
				chondral damage									
Stake et al. [121]	21/21 HIPS Group 1 [Worker's comp]	14%(3)	39(24-55)	Labral tear	NR	NR	HOS-SS	2 yr (min)	19 to 24	15.3±12.8	49.8±28.2	-1.54[-2.24 to -0.85]	Statistically significant change both groups (p<0.001)
	21/21 HIPS Group 2 [No worker's comp]	14%(3)	NR	Labral tear	NR	NR	HOS-SS	2 yr (min)	19 to 24	41.9±21.5	73.8±22.5	-1.42[-2.11 to -0.74]	
Stone et al [152]	100/100 Group 1 [no generalised laxity]	100%(100)	23±9	FAI/FAIS	Routine physical exercise (87%); Running as primary exercise(64%)	NR	HOS-SS	29.3±6 8 mo	≥ 25	NR	NR		Change score 37 ±26.7
	25/25 Group 2 [generalised laxity]	100%(25)	18±6	FAI/FAIS	Routine physical exercise (96%); Running as primary exercise(52%)	NR	HOS-SS	29.3±6 8 mo	≥ 25	NR	NR		Change score 35.1±27.3
Suarez-Ahedo et al. [122]	825/825 Group 1 [<34.6 years]	64%(531)	NR	Not specified	NR	NR	HOS-SS	28.98 mo [whole group]	≥ 25	43.5±25.4	73.4±40.8	-0.88[-0.98 to -0.78]	
	872/872 Group 2 [>34.6 years]	63%(505)	NR	Not specified	NR	NR	HOS-SS			35.6±24.8	61.9±30.8	-0.94[-1.04 to -0.84]	
Vap et al. [125]	72/72 Group 1 [Trochanteric Bursitis]	75%(54)	37	FAI/FAIS	NR	NR	HOS-SS	42±9.9 mo	≥ 25	49.0±24.0	78.0±28.0	-1.11[-1.46 to 0.75]	
	72/72 Group 2 [No trochanteric Bursitis]	75%(54)	37	FAI/FAIS	NR	NR	HOS-SS	42±9.1 mo	≥ 25	45.0±24.0	77.0±27.0	-1.25[-1.60 to -0.89]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Weber et al. [127]	17/17 Group 1 [High level athletes]	53%(9)	18±8	FAI/FAIS	"High level"	Cutting (17%); Flexibility (23%); Contact (12%); Impingement (1%); Asymmetric /overhead (17%); Endurance (30%)	HOS-SS	2 yr (min)	19 to 24	41.9±18.4	83.2±19.6	-2.12[-2.98 to -1.26]	
	49/49 Group 2 [Rec athletes]	63%(31)	30±9	FAI/FAIS	Recreational	NR	HOS-SS	2 yr (min)	19 to 24	41.9±21.6	79.0±23.3	-1.64[-2.10 to -1.18]	
Wu et al. [128]	68/68 Group 1 [No dysplasia]	63%(43)	42±9	Labral tear	NR	NR	HOS-SS	29.1±4.5 mo	≥ 25	50.3±8.9	88.9±5.2	-5.27[-5.98 to -4.55]	
Yoo et al. [129]	28/28 Group 1 [Military]	0%(0)	21±2	FAI/FAIS	Active military service	NR	UCLA	3.5±2.5 yr	≥ 25	6.1±NR	9.4±NR		Statistically significant change in both groups (p <0.001)
	28/28 Group 2 [Non military]	0%(0)	23±3	FAI/FAIS	Active non-military	NR	UCLA	3.7±2 yr	≥ 25	5.4±NR	8.4±NR		
Retrospective Studies, single-arm													
Barastegui et al. [40]	21/21	0%(0)	27±7	FAI/FAIS	Professional	Cutting	HOS-SS	45.4±5.6 mo	≥ 25	37.6±NR	86.7±NR		'Statistically significant differences observed' - values not reported.
Bayley et al. [41]	76/76	67%(51)	20±3	Labral tear	NR	NR	HOOS-SR	1 yr	7 to 12	38.8±27.4	60.5±29.4	-0.76[-1.09 to -0.43]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Beck et al [134]	108/108	NR	41±13	NR	NR	NR	HOS-SS	32.9m±9.3	≥ 25	40.1±26.6	73.4±28.6	-1.20 [-1.49 to -0.91]	
Chahla et al. [139]	189/153	71%(109)	34±13	FAI/FAIS	'Self report - any physical activity'	NR	HOS-SS	2 yr	≥ 25	42.9±21.7	76.3±21.2	-1.55 [-1.81 to -1.30]	
Chambers et al [141]	156/142	49%(70)	36±12	FAI/FAIS	NR	NR	HOOS-SR	1 yr	19 to 24	40.5±27.7	72.9±24.2	-1.41 [-1.67 to -1.15]	
Chandrasekaran et al. [45]	22/22	64%(14)	32±10	Labral tear	NR	NR	HOS-SS	2 yr	19 to 24	42.3±22.3	65.4±28.4	-0.89[-1.51 to -0.27]	
Chandrasekaran et al. [46]	55/52	84%(46)	24(13-38)	Boarderline dysplasia	NR	NR	HOS-SS	25.4(24-30.4) mo	≥ 25	46.6±NR	74.8±NR		Pre to post-op change HOS-SS = 27.6 (95%CI 20.0 to 35.2); p<0.001
Chandrasekaran et al. [48]	1137/1137	74%(840)	37(13-76)	Not specified	NR	NR	HOS-SS	2 yr	19 to 24	41.3±24.2	64.4±30.4	-0.84[-0.93 to -0.75]	
Cvetanovich et al. [52]	474/386	61%(251) [HIPS]	33±12	FAI/FAIS	NR	Endurance (58%);	HOS-SS	2.6±0.6 yr	≥ 25	43.9±23.4	72.2±27.3	-1.11[-1.26 to -0.96]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
						'Sport/hobbies' (72%)							
Degen et al. [54]	70/34	0%(0)	22±5	FAI/FAIS	Professional 27.1%(19); College 57.1%)(40) High school 8.6%(6); Club/team 7.1%(5)	Asymmetric /overhead	HOS-SS	2 yr	19 to 24	51.3±24.8	92.3±8.2	-1.95[-2.44 to -1.45]	
Domb et al. [66]	26/22	82%(18)	20(14-39)	Boarderline dysplasia	NR	NR	HOS-SS	27.5±5.5 mo	≥ 25	49.0±15.6	77±21.9	-1.45[-2.12 to -0.78]	
Domb et al. [67]	60/60	73%(47) [HIPS]	29±12	Labral tear	NR	NR	HOS-SS	67.8±7.4 mo	≥ 25	47.1±23.2	76.5±25.9	-1.19[-1.58 to -0.80]	
Domb et al. [57]	24/19	89%(17)	23±8	Boarderline dysplasia	NR	NR	HOS-SS	68.8±6.4 mo	≥ 25 mo	52.1±15.9	70.8±19.5	-1.03[-1.71 to -0.35]	
Flores et al. [35]	122/49	53%(68) [HIPS]	36±11	FAI/FAIS; Labral tear	NR	NR	HOOS-SR	2 yr	19 to 24	39.9±22.4	75.3±23.6	-1.55[-1.92 to -1.18]	
Frank et al. [75]	62/58	62%(36)	30±7	FAI/FAIS	Recreational	Endurance (cycling)	HOS-SS	31.14±0.71 mo	≥ 25	41.5±23.2	85.2±16.0	-2.18[-2.64 to -1.72]	No significant change to average miles cycled/week: 30.3±42.4 [range 2 to 300] pre-op; 23.8±22.9 [range not reported] post-op, (p=0.08).
Frank et al [73]	44/42	90%(38) [HIPS]	35±9	FAI/FAIS	NR	Flexibility	HOS-SS	30.5±12 mo	≥ 25	48.0±23.7	85.9±12.9	-1.96[-2.47 to -1.44]	No significant change to average hours/week of yoga: 2.7±1.9 pre-op; 2.5±1.3 post-op, (p=0.44).

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Frank et al. [74]	27/26	62%(16)	31±7	FAI/FAIS	Amateur 23%(6) Recreational 73%(20)	Endurance (swimming)	HOS-SS	2 yr	19 to 24	44.0±21.0	85.2±16.0	-2.17[-2.87 to -1.48]	No significant change to average miles/week swimming: 0.4±0.8 [range, 0.2-1.02] pre-op; 0.36±0.74 post-op (p=0.86)
Gupta et al [78]	595/595	62%(367)	38(13-76)	Not specified	NR	NR	HOS-SS	29(24-66.1) mo	≥ 25	41.0±25.0	70.1±28.0	-1.09[-1.22 to -0.97]	
Hartigan et al. [81]	78/78	70%(57)	23(14-39)	Retroverted acetabula	NR	NR	HOS-SS	38.7(22.1–77.6) mo	≥ 25	47.3±NR	76.4±NR		Statistically significant change (p<.0001)
Hartigan et al. [82]	69/65	37%(41)	44(16-63)	Labral pathology; Subchondral cysts	NR	NR	HOS-SS	2 yr (min)	19 to 24	41.0±NR	63.0±NR		Statistically significant change (p<0.001)
Hevesi et al. [84]	303/303	67%(202)	32±12.2	Labral tear	NR	NR	HOS-SS	5 to 7.9 yr	≥ 25	NR±NR	NR±NR		Change score -29.3
Ibrahim et al. [85]	88/88	35%(31)	31(17-48)	Cam FAI	NR	NR	HOOS-SR	2.7 (1 to 8) yr	≥ 25	44.4±27.0	61.7±28.1	-0.63[-0.93 to -0.32]	
Kang et al.[88]	41/41	29%(12)	26(12-65)	FAI/FAIS; Labral tear	Athletic - >4hr/day 5 day/week in specific sport	Cutting (11%); Flexibility (49%); Asymmetric /overhead (20%); Endurance (20%)	HOS-SS	27 (16 to 53) mo	≥ 25	43%±NR	75%±NR		Statistically significant change (p=0.032)
Klingenstein et al. [90]	34/23	15%(5)	21(16-35)	FAI/FAIS	Professional 27% (9); Varsity high school 29%(10); College 44%(15)	Asymmetric /overhead	HOS-SS	25(12 to 41) mo	≥ 25	NR±NR	86.0±18.0		Statistically significant change: mean change=36 (p<0.01)

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Lansdown et al. [93]	707/585 (HOS-SS)	64%(456)	33±12	FAI/FAIS	NR	NR	HOS-SS	2 yr (min)	19 to 24	43.4±23.1	72.6±27.2	-1.16[-1.28 to -1.03]	
Lee et al [149]	45/41 HIPS	49%(20)	35(16-54)	FAI/FAIS; Labral tear	NR	NR	HOS-SS	92.4 (85 to 117) mo	≥ 25	51.2±NR	82.4±NR		
Levy et al. [95]	51/46	57%(29)	26±8	FAI/FAIS	Competitive runners; Recreational runners	Endurance	HOS-SS	2 yr	19 to 24	47.7±20.6	83.7±18.2	-1.84[-2.33 to -1.35]	significant change to average miles/week running & hours/week running: 9.6±6.5 miles & 4.6±3.1 hours **pre-injury;** 6.4±5.8 miles (p<0.001) & 3.0±2.4 hours post-op (p<0.001).
Lund et al. [99]	1835/1835	53%	38(9-79)	FAI/FAIS	NR	NR	HAGOS-SR	2 yr	20 to 24	36.0±23.0	60.0±28.1	-0.93[-1.00 to -0.87]	
							HAGOS-PA	2 yr	21 to 24	21.0±24.5	47.0±35.7	-0.85[-0.92 to -0.78]	
							HSAS	2 yr	22 to 24	2.5±1.9	3.3±2.0	-0.41[-0.48 to -0.34]	
Más Martínez et al. [101]	41/36	0%(0)	33±7	FAI/FAIS	NR	Cutting; Flexibility; Impingement; Asymmetric /overhead; Endurance	HOS-SS	31.3±12.2 mo	≥ 25	28.6±18.4	95.4±5.9	-4.84[-5.77 to -3.90]	
Michal et al. [102]	39/34	47%(16)	33(18-61)	FAI/FAIS; subspine impingement	NR	NR	HOS-SS	24.8(13 to 37) mo	≥ 25	10.1±32.1	78.4±22.2	-2.45[-3.09 to -1.82]	Significant change in median scores[range] from 20[0–80] to 95[27–100], p<0.0001
Nwachukwu et al. [105]	364/364	57%(208)	33±10	FAI/FAIS	NR	NR	HOS-SS	1 yr	7 to 12	51.7±23.7	78.0±23.9	-1.10 [-1.26 to -0.95]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Ortiz-Declet et al. [106]	49/40	40%(16)	49±12	Not specified	NR	Asymmetric /overhead	HOS-SS	2 yr (min)	19 to 24	47.7±26.5	64.4±28.2	-0.61[-1.03 to -0.18]	
Perets et al. [109]	49/39	80%(31)	19±5	FAI/FAIS; Borderline dysplasia; Labral tear; Hypermobility	Professional; High school; Collegiate	Cutting (15%); Flexibility (15%); Contact (6%); Asymmetric /overhead (32%); Endurance (32%)	HOS-SS	33.6(24 to 64.5) mo	≥ 25	46.8±23.4	80.1±22.9	-1.42[-1.92 to -0.92]	
Perets et al. [111]	62/62	71%(47) [HIPS]	21±8	Not specified	Professional 14%(9 hips) Collegiate 30%(20 hips); High school 56% (37 hips);	Cutting (38%); Flexibility (10%); Contact (6%); Impingement (9%); Asymmetric /overhead (12%); Endurance (25%)	HOS-SS	>5 yr	≥ 25	47.0±22.4	79.1±23.0	-1.41[-1.80 to -1.01]	
Pergaminelis et al. [112]	35/35	89%(31)	38(16-67)	Lig teres tear	NR	*[Only reported for 51%]* Cutting (23%); Flexibility (11%); Impingement (6%); Endurance (11%)	iHOT-33 SR	17.7(6 to 42) mo	13 to 18	15.0±16.1	31.9±22.6	-0.85[-1.34 to -0.36]	
Rhee et al. [115]	37/37	19%(7)	36±8	Chondral lesions	NR	NR	HOS-SS	12.7±7.3 mo	7 to 12	36.9±24.9	51.6±31.0	-0.52[-0.98 to -0.05]	

	n Baseline/Final follow up	Women %(n)	Age in years mean± SD*	Inclusion pathology	Physical activity attributes %(n)	Activity category	Outcome	Reported duration of follow-up	Category (months)	Pre-intervention mean±SD	Final score mean±SD	Effect size[95%CI]	Study conclusions where effect size unable to be calculated
Riff et al. [116]	32/32	59%(19)	35±7	FAI/FAIS	NR	Endurance	HOS-SS	2 yr (min)	19 to 24	49.2±21.2	83.3±21.4	-1.58[-2.15 to -1.02]	No significant change in average hours/week HIIT: 5.3±2.4 **pre-injury**; 5.1±3.6 post-op, (p=0.8).
Shaw et al. [120]	11/11	27%(3)	34(27-43)	Not specified	Active military service	NR	HOS-SS	6 mo	≤ 6	56.7±10.9	93.7±5.0	-4.21[-5.82 to -2.61]	
Stone et al.[151]	780/626	70%(437)	35(16-54)	FAI/FAIS; Labral tear	Recreational (74%); High school (10%); College (7%); Professional (2%)	NR	HOS-SS	92.4(85 to 117) mo	≥ 25	43.9±22.0	77.9±23.5	-2.16 [-2.60 to -1.72]	
Ukwuani et al [153]	69/64	97%(62)	22±9	FAI/FAIS	Competitive (51%); Intermediate (33%); Recreational (6%)	Flexibility	HOS-SS	23±12.2 mo	19 to 24	40.3±20.3	83.5±19.4	-2.16 [-2.60 to -1.72]	
Waterman et al. [126]	29/29	21%(6)	36±12	FAI/FAIS	NR	Asymmetric /overhead		2 yr (min)	19 to 24	38.2±23.5	79.7±28.8	-1.56[-2.15 to -0.97]	No significant change in average number of holes/ week: 49.2±36.8 pre-op; 45.9±38.8 post-op, (p value not reported).

*range is reported where no SD available; n=number of participants; SD=standard deviation; NR=Not reported; FAA=Functional Activity Assessment; HAGOS-PA/SR= The Copenhagen Hip and Groin Outcome Score – Participation in Physical Activities/ Physical Function in Sport and Recreation; HOOS-SR= Hip disability and Osteoarthritis Outcome Score – Function in Sport and Recreation ; HOS-SS= Hip Outcome Score – Sport Scale; HSAS= Hip Sports Activity Scale; iHOT-33 SR= International Hip Outcome Tool –Sports and Recreational activities; Tegner= Tegner Activity Scale; UCLA= The University of California at Los Angeles activity score; PT=physiotherapist; rehab=rehabilitation; Self-reported PA hr/week=self-reported physical activity hours/week; Lig=ligamentum; SDLP=labral preservation group; decomp=decompression; IFL=Iliopsoas fractional lengthening; comp=compensation; Rec=recreational; FAI/FAIS=femoroacetabular impingement/syndrome; min=minimum; op=operative; PRP=platelet rich plasma; wk=week; yr=year; mo=month; d=day; HIIT=High Intensity Interval Training.

Additional file 5 – Overview of patient reported outcomes identified in the review.

Additional file 5. Overview of patient-reported outcomes identified in the review.

Patient-reported outcome	Duration of recall	Scale	
HOS-SS *Hip Outcome Score – Sport Scale* (Martin 2006)	Over the last week	Six-point Scale 'No difficulty' to 'Unable'	Because of your hip, how much difficulty do you have with: ▪ Running 1 mile ▪ Jumping ▪ Swinging objects like golf club ▪ Landing ▪ Start and stop quickly ▪ Cutting/lateral movements ▪ Low impact like fast walking ▪ Perform activity with normal technique ▪ Ability to participate in desired sport for as long as you would like. ▪ How would you rate your current level of function compared with prior to hip problem (0 to 100%) ▪ How would you rate your current level of function (normal, nearly normal, abnormal, severely abnormal)
HAGOS-SR *The Copenhagen Hip and Groin Outcome Score – Physical Function in Sport and Recreation* (Thorborg et al 2011)	Over the last week	Five-point scale 'None' to 'Extreme'	What degree of difficulty have you experienced during the following activities due to problems with your hip and/or groin. ▪ Squatting ▪ Running ▪ Twisting / pivoting on WB leg ▪ Walking on uneven surface ▪ Running as fast as you can ▪ Bringing the leg forward and/or out to the side such as in kicking, skating, etc. ▪ Sudden explosive movements that involve quick movements such as acceleration, deceleration, change of direction, etc ▪ Situation where the leg is stretched in an outer positions (such as when the leg is placed as far away from the body as possible).
HAGOS-PA *The Copenhagen Hip and Groin Outcome Score – Participation in Physical Activities* (Thorborg et al 2011)	Over the last week	Five-point scale 'Always' to 'Never'	Consider to what degree your ability to participate in physical activities has been affected by your hip and/or groin pain problem. Are you able to participate in your preferred physical activities… ▪ for as long as you would like ▪ at your normal performance level
HOOS-SS *Hip disability and Osteoarthritis Outcome Score – Function in Sport and Recreation* (Nilsdotter et al 2003)	Over the last week	Five-point scale 'None' to 'Extreme'	What degree of difficulty have you experienced with the following activities due to your hip? ▪ Squatting ▪ Running ▪ Twist/pivot on loaded leg ▪ Walking on uneven surface
iHOT-33 SR *International Hip Outcome Tool –Sports and Recreational activities* (Mohtadi et al 2012)	Over the last month	Visual Analogue Scale 'Extreme' to 'none'	▪ How concerned are you about your ability to maintain desired fitness level? ▪ How much pain do you experience in your hip after activity? ▪ How concerned are you that the pain in your hip will increase if you participate in sports or recreational activities? ▪ How much has you quality of life deteriorated because you cannot participate in sport/recreational activities? ▪ How concerned are you about cutting/changing direction during your sport and recreational activities?

			▪ How much has your performance level decreased in you sport and recreational activities?
Tegner *Tegner Activity scale* (Tegner at al 1985)	Current level	Classification of level of sport and physical activity (including work)	0=sick leave to 10=international elite
HSAS *Hip Sports Activity Scale* (Naal et al 2013)	Current highest level	Classification of level of sport activity	0=no recreational or competitive sports to 8=competitive sports (Elite level)
UCLA Activity score *The University of California at Los Angeles activity score*	Current activity level	Classification of level of activity	1=wholly inactive, dependent on others and can not leave residence to 10=Regularly participates in impact sports

Additional file 6 – Data from intermediate time-points

Additional file 6: Data from intermediate time points (not reported in additional file 4)

			Baseline		Time point 1				Time point 2				Time point 3			
Study	Outcome measure	Group (where applicable)	n	Mean±SD or [Range]	Reported duration	Timepoint category	n	Mean±SD or [Range]	Reported duration	Timepoint category	n	Mean±SD or [Range]	Reported duration	Timepoint category	n	Mean±SD or [Range]
Randomised Controlled Trials																
Mansell et al. [100]	HOS-SS	Surgical	66	52.6 [78.4 to 56.7]	6 mo	≤ 6 mo	66	47.9 [41.3 to 54.5]	1 yr	7 to 12 mo	66	52.1 [45.3 to 59]		7 to 12 mo	666	
Bennell et al. [131]	HOS-SS	Group 1 (PT rehab)	14	50.9±17.1	14 wk	≤ 6 mo	14	83.6±18.1								
	HOS-SS	Group 2 (no PT rehab)	16	52.1±16.7	14 wk	≤ 6 mo	14	70.8±18.6								
	HAGOS-SR	Group 1 (PT rehab)	14	35.9±16.9	14 wk	≤ 6 mo	14	43.9±19.3								
	HAGOS-SR	Group 2 (no PT rehab)	16	43.9±19.3	14 wk	≤ 6 mo	14	61.6±19.8								
	Tegner	Group 1 (PT rehab)	14	3.9±1.8	14 wk	≤ 6 mo	14	4.8±1.3								
	Tegner	Group 2 (no PT rehab)	16	4.3±2.2	14 wk	≤ 6 mo	14	5.1±2.0								
	HSAS	Group 1 (PT rehab)	14	31±18.0	14 wk	≤ 6 mo	14	39.5±14.2								
	HSAS	Group 2 (no PT rehab)	16	31.9±21.6	14 wk	≤ 6 mo	14	30.4±20.8								
Prospective Studies, more than 1 arm (Only groups meeting criteria reported)																
Redmond et al. [114]	HOS-SS	Group 1 (+PRP)	104	41.3±NR	3 mo	≤ 6mo	NR	61.4±NR								
		Group 2 (-PRP)	202	43.5±NR	3 mo	≤ 6mo	NR	61.8±NR								
Thorborg et al. [18]	HAGOS-SR		97	39.0±19.7	3 mo	≤ 6mo	91	58.4±25.1	6 mo	≤ 6mo	85	65.1±23.4				
	HAGOS-PA		97	19.8±24.2	3 mo	≤ 6mo	90	36.5±33.4	6 mo	≤ 6mo	85	47.8±35.4				
Prospective Studies, single arm																
Domb et al. [63]	HOS-SS		42	40.2±23.2	2yr	19 to 24mo	42	65.2±32.7								
Tahoun et al. [123]	HOS-SS		23	30.9±13.9	1yr	7 to 12 mo	23	64.8±26.3								
Retrospective Studies, more than 1 arm (Only groups meeting criteria reported)																
Frank et al. [71]	HOS-SS	Group 1 [Partial closure]	32	39.4±23.9	6 mo	≤ 6 mo	32	63.8±31.1	12 mo	7 to 12 mo	32	72.7±14.7				
	HOS-SS	Group 2 [Complete closure]	32	39.0±24.2	6 mo	≤ 6 mo	32	72.2±16.1	12 mo	7 to 12 mo	32	82.5±10.7				
Gupta et al. [77]	HOS-SS	Group1 [Obese]	87	25.4±22.3	3 mo	≤ 6 mo	62	51.7±35.4	1 yr	7 to 12 mo	62	43.8±36.6				
	HOS-SS	Group 2 [Control	364	42.0±24.2	3 mo	≤ 6 mo	124	58.1±31.5	1 yr	7 to 12 mo	124	71.5±28.2				

			Baseline		Time point 1				Time point 2				Time point 3			
Study	Outcome measure	Group (where applicable)	n	Mean±SD or [Range]	Reported duration	Timepoint category	n	Mean±SD or [Range]	Reported duration	Timepoint category	n	Mean±SD or [Range]	Reported duration	Timepoint category	n	Mean±SD or [Range]
Hartigan et al. [80]	HOS-SS	Group 1 [Retroversion]	59	45.7±25.5	3 mo	≤ 6 mo	59	66.9±NR	12 mo	7 to 12 mo	59	63.7±NR				
	HOS-SS	Group 2 [Normal version]	59	44.8±23.8	3 mo	≤ 6 mo	59	62.0±NR	12 mo	7 to 12 mo	59	69.4±NR				
Hartigan et al. [79]		Group 1 [Microfracture]	15	26.7±21.6	3 mo	≤ 6 mo	15	39.0±NR	1 yr	7 to 12 mo	15	59.0±NR				
		Group 2 [No microfracture]	45	42.3±26.1	3 mo	≤ 6 mo	45	52.3±NR	1 yr	7 to 12 mo	45	65.4±NR				
Lodhia et al. [97]		Group 1 [Microfracture]	35	42.1±24.18	3 mo	≤ 6 mo	35	51.5±34.5	1 yr	7 to 12 mo	35	58.6±23.4	2 yr	19 to 24mo	35	65.7±26.8
		Group 2 [Control]	70	37.6±25.1	3 mo	≤ 6 mo	70	62.1±28.7	1 yr	7 to 12 mo	70	65.4±27.1	2 yr	19 to 24mo	70	71.5±26.2
Retrospective Studies, single-arm																
Barastegui et al. [40]	HOS-SS		21	37.6±NR	6mo	≤ 6 mo	21	81.1±NR	12 mo	7 to 12 mo	21	88.6±NR	24 mo	19 to 24mo	21	90.3±NR
Chandrasekaran et al [45]	HOS-SS		22	42.3±22.3	3mo	≤ 6 mo	22	48.4±35.1	12 mo	7 to 12 mo	22	55.7±36.5				
Domb et al. [57]	HOS-SS		60	47.1±23.2	2 yr	19 to 24mo	60	76.0±25.5	67.8±7.4mo						60	
Flores et al. [35]	HOOS-SS		128	39.9±22.4	3mo	≤ 6 mo	NR	67.4±22.0	6 mo	≤ 6 mo	NR	73.3±22.8	1 yr	7 to 12 mo	122	74.1±24.0
Lund et al. [99]	HAGOS-SR		1835	36.0±23.0	1 yr	7 to 12 mo	1835	60.0±28.8	2 yr							
	HAGOS-PA		1835	21.0±24.5	1 yr	7 to 12 mo	1835	45.0±34.6								
	HSAS		1835	2.5±1.9	1 yr	7 to 12 mo	1835	3.1±2.0								
Perets et al. [111]	HOS-SS		62	47±22.4	2 yr	19 to 24mo	62	77.3±25.6								

n=number of participants; SD=standard deviation; NR=Not reported; HAGOS-PA/SR= The Copenhagen Hip and Groin Outcome Score – Participation in Physical Activities/ Physical Function in Sport and Recreation; HOS-SS= Hip Outcome Score – Sport Scale; HSAS= Hip Sports Activity Scale; Tegner= Tegner Activity Scale; wk=week; yr=year; mo=month; PT=physiotherapy; PRP=platelet rich plasma

Additional material 7 – Inclusion and exclusion criteria, findings and intervention.

Excel file can be accessed online at: https://doi.org/10.1186/s40798-020-0234-8

Additional file 8 – Risk of bias assessment.

Additional file 8: Quality assessment for all included studies.

		External Validity		Internal Validity: Performance	Internal Validity: Detection				Attrition	Selection bias/control of confounding						
Study	Country	Representative	[1]Participation rate	Direct observation	PROM -validity/ reliability	[2]Direct observation - validity/ reliability	Blinded assessors	[3]Outcome measure	[1]Completeness	[4]Age	Location	[5]Gender	[6]Severity of Joint disease	[7]Follow-up	Single site &/or surgeon	LOE
RCTs																
Bennell et al. [131]	Australia	✓	✓	✓	✓	NA	✓	✓	×	×	✓	×	✓	✓		2
Mansell et al. [100]	USA	✓	✓	✓	✓	NA	✓	✓	×	✓	✓	×	✓	×	YES	2
Prospective Studies, more than 1 arm																
Chaharbakhshi et al [43]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	3
Domb et al. [58]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	3
Flores [69]	USA	✓	✓	✓	✓	NA	×	✓	✓	×	✓	✓	✓	×	YES	3
Flores et al. [70]	USA	✓	✓	✓	✓	NA	×	✓	✓	×	✓	×	✓	×	YES	3
Glaws et al. [76]	USA	✓	✓	✓	✓	NA	×	✓	×	×	✓	×	✓	×	YES	3
Kemp et al. [89]	Australia	✓	✓	✓	✓	NA	✓	✓	×	×	✓	×	×	×	YES	3
Kierkegaard et al.[154]	Denmark	✓	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	×	YES	3
Krych et al. [91]	USA	✓	✓	✓	✓	NA	×	✓	✓	×	✓	✓	✓	×	YES	3
Newman et al. [104]	USA	×	✓	✓	✓	NA	×	✓	✓	✓	✓	✓	✓	×	YES	3
Redmond et al. [113]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	×	×		3
Redmond et al. [114]	USA	×	✓	✓	×	NA	×	✓	✓	×	×	✓	×	×	YES	3
Thorborg et al. [18]	Denmark	✓	✓	✓	✓	NA	×	✓	✓	×	✓	✓	✓	✓	YES	3
Zimmerer et al. [130]	Germany	✓	✓	✓	✓	NA	×	✓	✓	✓	✓	×	✓	×	YES	3
Prospective, single arm																
Bennett et al. [42]	UK	×	×	×	✓	NA	×	✓	✓	✓	✓	✓	×	✓	YES	3
Chahal et al [37]	USA	×	×	✓	✓	NA	×	✓	×	×	✓	×	✓	×	YES	3
Davis et al. [53]	USA	×	×	✓	✓	NA	×	✓	✓	×	✓	✓	✓	×	YES	3
Domb et al. [63]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	3
Ishoi et al [17]	Denmark	✓	×	✓	×	NA	×	✓	×	✓	✓	✓	✓	×		3
Ohlin et al.[150]	Sweden	✓	✓	✓	✓	NA	×	✓	×	×	✓	×	✓	×		3
Philippon [132]	USA	✓	✓	✓	✓	NA	×	✓	✓	×	✓	×	×	×	YES	4
Sansone et al. [118]	Sweden	×	✓	✓	✓	NA	×	✓	✓	×	✓	×	×	×	YES	3

		External Validity		Internal Validity: Performance	Detection				Attrition	Selection bias/control of confounding						
Study	Country	Representative	[1]Participation rate	Direct observation	PROM -validity/ reliability	[2]Direct observation - validity/ reliability	Blinded assessors	[3]Outcome measure	[1]Completeness	[4]Age	Location	[5]Gender	[6]Severity of Joint disease	[7]Follow-up	Single site &/or surgeon	LOE
Sansone et al. [6]	Sweden	×	✓	✓	✓	NA	×	✓	×	×	✓	×	✓	×	YES	3
Tahoun et al. [123]	Spain/Egypt	×	×	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Tijssen et al. [124]	Netherlands	✓	✓	✓	×	NA	✓	✓	✓	×	✓	×	×	×	YES	3
Retrospective, more than1 arm																
Basques et al.[133]	USA	✓	✓	✓	✓	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Beck et al. [135]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Bolia et al.[136]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Cancienne et al [137]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	×	×	YES	4
Chaharbakhshi et al. [138]	USA	✓	×	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Chahla et al. [140]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Chandrasekaran et al. [142]	USA	✓	✓	✓	×	NA	×	✓	×	×	✓	✓	✓	×	YES	4
Chandrasekaran et al. [47]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Chandrasekaran et al. [49]	USA	×	✓	✓	×	NA	×	✓	×	×	✓	×	✓	×	YES	4
Chandrasekaran et al. [44]	USA	✓	✓	✓	×	NA	✓	✓	✓	×	✓	✓	✓	×	YES	4
Chen et al. [50]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Clapp et al.[143]	USA	×	✓	✓	×	NA	×	✓	×	×	✓	✓	✓	×	YES	4
Cvetanovich et al [51]	USA	✓	✓	✓	✓	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Degen et al. [55]	USA	✓	✓	✓	×	NA	×	✓	✓	✓	✓	✓	×	×	YES	4
Domb et al. [60]	USA	✓	✓	✓	×	NA	×	✓	×	×	✓	×	✓	×	YES	4
Domb et al. [59]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Domb et al. [62]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Domb et al. [64]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Domb et al. [65]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Domb et al. [56]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Domb et al. [61]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Fabricant et al [68]	USA	✓	✓	✓	×	NA	×	×	✓	×	✓	✓	✓	×	YES	4

		External Validity		Internal Validity												
				Performance	Detection				Attrition	Selection bias/control of confounding						
Study	Country	Representative	[1]Participation rate	Direct observation	PROM -validity/ reliability	[2]Direct observation - validity/ reliability	Blinded assessors	[3]Outcome measure	[1]Completeness	[4]Age	Location	[5]Gender	[6]Severity of Joint disease	[7]Follow-up	Single site &/or surgeon	LOE
Frank et al. [144]	USA	×	✓	✓	×	NA	×	✓	×	×	✓	✓	✓	×	YES	4
Frank et al. [71]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	×	✓	YES	4
Frank et al. [72]	USA	×	×	✓	×	NA	×	✓	✓	×	✓	✓	×	×	YES	4
Gupta et al. [77]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Hartigan et al. [79]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Hartigan et al. [80]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Hassebrock et al. [145]	USA	✓	✓	✓	×	NA	×	✓	✓	✓	✓	×	✓	×	YES	4
Hevesi et al [146]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×		4
Hevesi et al [83]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×		4
Jackson et al. [86]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	×	×	YES	4
Jackson et al. [87]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	×	×	YES	4
Krishnamoorthy et al.[147]	USA	✓	✓	✓	×	NA	×	✓	×	×	✓	✓	✓	×	YES	4
Kuhns et al. [92]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Kunze et al.[148]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Levy et al. [94]	USA	✓	✓	✓	×	NA	×	✓	✓	×	×	✓	×	×	YES	4
Locks et al. [96]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	✓	YES	4
Lodhia et al. [97]	USA	×	✓	✓	×	NA	×	✓	×	×	✓	✓	✓	×	YES	4
Lodhia et al. [98]	USA	✓	×	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Nawabi et al. [103]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	✓	×	×	YES	4
Perets et al. [108]	USA	✓	✓	✓	×	NA	×	✓	×	×	✓	×	✓	×	YES	4
Perets et al. [110]	USA	✓	✓	✓	×	NA	×	✓	×	×	✓	✓	✓	×	YES	4
Perets et al. [107]	USA	✓	✓	✓	×	NA	×	×	✓	✓	✓	✓	✓	×	YES	4
Saltzman et al. [117]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Sawyer et al. [119]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Stake et al. [121]	USA	×	✓	✓	×	NA	×	×	×	×	✓	✓	✓	×	YES	4

		External Validity		Internal Validity: Performance	Detection				Attrition	Selection bias/control of confounding						
Study	Country	Representative	[1]Participation rate	Direct observation	PROM -validity/ reliability	[2]Direct observation - validity/ reliability	Blinded assessors	[3]Outcome measure	[1]Completeness	[4]Age	Location	[5]Gender	[6]Severity of Joint disease	[7]Follow-up	Single site &/or surgeon	LOE
Stone et al. [152]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Suarez-Ahedo et al. [122]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Vap et al. [125]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	✓	×	×	YES	4
Weber et al. [127]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Wu et al. [128]	China	×	×	✓	×	NA	×	✓	×	×	✓	✓	✓	×	YES	4
Yoo et al. [129]	Korea	×	×	✓	×	NA	×	✓	✓	✓	✓	✓	✓	×	YES	4
Retrospective, single arm																
Barastegui et al. [40]	Spain	×	✓	✓	×	NA	×	✓	✓	×	✓	×	×	×	YES	
Bayley et al. [41]	Canada	✓	✓	✓	×	NA	×	×	✓	×	✓	×	✓	×	YES	4
Beck et al. [134]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Chahla et al. [139]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Chambers et al. [141]	USA	✓	✓	✓	✓	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Chandrasekaran et al. [45]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Chandrasekaran et al. [46]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Chandrasekaran et al. [48]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Cvetanovich et al. [52]	USA	✓	✓	✓	✓	NA	✓	✓	✓	×	✓	×	✓	×	YES	4
Degen [54]	USA	✓	✓	×	×	NA	×	✓	×	×	✓	×	✓	×	YES	4
Domb et al. [57]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Domb et al. [66]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Domb et al. [67]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Flores et al. [35]	USA	✓	✓	✓	✓	NA	×	✓	×	×	✓	✓	✓	×	YES	4
Frank et al [73]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Frank et al.[74]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Frank et al. [75]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Gupta et al [78]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Hartigan et al. [82]	USA	✓	✓	✓	✓	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Hartigan et al. [81]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4

		External Validity		Internal Validity: Performance	Detection				Attrition	Selection bias/control of confounding						
Study	Country	Representative	[1]Participation rate	Direct observation	PROM -validity/ reliability	[2]Direct observation - validity/ reliability	Blinded assessors	[3]Outcome measure	[1]Completeness	[4]Age	Location	[5]Gender	[6]Severity of Joint disease	[7]Follow-up	Single site &/or surgeon	LOE
Hevesi et al. [84]	USA	✓	✓	✓	×	NA	×	✓	✓	×	×	×	✓	×		4
Ibrahim et al. [85]	Canada	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Kang et al.[88]	Korea	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	×	×	YES	4
Klingenstein et al. [90]	USA	✓	✓	✓	×	NA	×	✓	×	×	✓	×	✓	×	YES	4
Lansdown et al. [93]	USA	✓	✓	✓	×	NA	×	✓	×	×	✓	×	✓	×	YES	4
Lee et al.[149]	Korea	×	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×		4
Levy et al. [95]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Lund et al. [99]	Denmark	✓	×	✓	✓	NA	×	✓	×	×	✓	✓	✓	×		4
Más Martínez et al. [101]	Spain	✓	✓	✓	×	NA	×	✓	✓	✓	✓	✓	✓	×	YES	4
Michal et al. [102]	Israel	×	✓	✓	×	NA	×	✓	✓	×	✓	✓	✓	×	YES	4
Nwachukwu et al. [105]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	×	×	YES	4
Ortiz-Declet et al. [106]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Perets et al. [109]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Perets et al. [111]	USA	×	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Pergaminelis et al. [112]	Australia	✓	✓	✓	✓	NA	×	✓	✓	×	✓	×	×	×		4
Rhee et al. [115]	Canada	×	✓	✓	×	NA	×	✓	✓	×	✓	×	×	×	YES	4
Riff et al. [116]	USA	✓	✓	✓	×	NA	×	✓	✓	✓	✓	×	✓	×	YES	4
Shaw et al. [120]	USA	✓	✓	✓	×	NA	×	✓	✓	✓	✓	×	×	×	YES	4
Stone et al. [151]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4
Ukwuani et al [153]	USA	✓	✓	✓	×	NA	×	✓	×	×	✓	×	✓	×	YES	4
Waterman et al. [126]	USA	✓	✓	✓	×	NA	×	✓	✓	×	✓	×	✓	×	YES	4

✓ indicates the measure was adequately addressed in the study. × indicates the measure was not adequately addressed in the study.

[1]✓ percent participation/ completion was 80% or more

[2]**NA** indicates no direct measure of PA used

[3]✓ indicates same method of ascertainment was used for all participants

[4]✓ if **range** within 18-50. × if range is outside 18-50 and not adjusted for in analysis or insufficient information

[5]✓ if gender is balanced (10% or less difference) or adjusted for in analysis; × >10% difference not adjusted for in analysis or unknown

[6]✓ if severity of OA identified in the study

		External Validity		Internal Validity												
				Performance	Detection				Attrition	Selection bias/control of confounding						
Study	Country	Representative	[1]Participation rate	Direct observation	PROM -validity/ reliability	[2]Direct observation - validity/ reliability	Blinded assessors	[3]Outcome measure	[1]Completeness	[4]Age	Location	[5]Gender	[6]Severity of Joint disease	[7]Follow-up	Single site &/or surgeon	LOE

[7]✓ where FU is the same for all study participants or lies within 10% i.e. the following acceptable ranges – 1 year follow-up, 1 month each way; 2 years follow-up = 2 months; 3 years follow-up = 3months……10 years = 10 months;
× differences in follow-up are >10% or unaccounted for in analysis

LOE=Level of evidence (Oxford Centre for Evidence-Based Medicine [29]); PROM=patient-reported outcome measure.

APPENDIX 3: COPIES OF ETHICAL APPROVAL DOCUMENTS, PATIENT INFORMATION STATEMENT AND INFORMED CONSENT, STUDY 2[110] & STUDY 3[112]

LA TROBE UNIVERSITY

University Human Ethics Committee

RESEARCH OFFICE

MEMORANDUM

To: **Professor Kay Crossley, School of Allied Health, College of SHE**

From: **Senior Human Ethics Officer, La Trobe University Human Ethics Committee**

Subject: **Review of Human Ethics Committee Application No. 16-082 Mod 1**

Title: **Validity and Reliability of wearable technology during incremental exercise**

Date: **30 January 2017**

Thank you for submitting your modification request for ethics approval to the La Trobe University Human Ethics Committee (UHEC) for the project referred to above. The UHEC has reviewed and approved the following modification/s which may commence now:

- **Increase in number of participants from 20 to 30**

Please note that your request has been reviewed by a sub-committee of the UHEC to facilitate a decision before the next Committee meeting. This decision will require ratification by the UHEC and it reserves the right to alter conditions of approval or withdraw approval at that time. However, you may commence prior to ratification and you will be notified if the approval status of your project changes.

The following standard conditions apply to your project:

- **Limit of Approval.** Approval is limited strictly to the research proposal as submitted in your application while taking into account any additional conditions advised by the UHEC.

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

- **Adverse Events.** If any unforeseen or adverse events occur, including adverse effects on participants, during the course of the project which may affect the ethical acceptability of the project, the Chief Investigator must immediately notify the UHEC Executive Officer on telephone (03) 9479 1443. Any

complaints about the project received by the researchers must also be referred immediately to the UHEC Executive Officer.

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

- **Monitoring.** All projects are subject to monitoring at any time by the UHEC.

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

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

- **Final Report.** A Final Report (see above address) is required within six months of the completion of the project or by **14 June 2018.**

If you have any queries on the information above please e-mail: **humanethics@latrobe.edu.au** or contact me by phone.

Kind regards

Ms Sara Paradowski
Senior Human Ethics Officer
Executive Officer – University Human Ethics Committee
Ethics and Integrity / Research Office
La Trobe University Bundoora, Victoria 3086
P: (03) 9479 – 1443 F: (03) 9479 - 1464
http://www.latrobe.edu.au/researchers/ethics/human-ethics

Ethics Approval Document, Study 2 and 3 - HEC16-082

Fri 14/10/2016, 09:56

Dear Kay Crossley,

The following project has been assessed as complying with the National Statement on Ethical Conduct in Human Research. I am pleased to advise that your project has been granted ethics approval and you may commence the study.

Application ID: HEC16-082

Application Status/Committee: Finalised - Approved

Project Title: VALIDITY AND RELIABILITY OF WEARABLE TECHNOLOGY DURING INCREMENTAL EXERCISE.

Chief Investigator: Kay Crossley

Other Investigators: Benjamin Dascombe, Joanne Kemp, Denise Jones

Date of Approval: 14/10/2016

Date of Ethics Approval Expiry: 14/12/2017

The following standard conditions apply to your project:

Limit of Approval. Approval is limited strictly to the research proposal as submitted in your application.

- Variation to Project. Any subsequent variations or modifications you wish to make to your project must be formally notified for approval in advance of these modifications being introduced into the project.

- Adverse Events. If any unforeseen or adverse events occur the Chief Investigator must immediately notify the UHEC immediately. Any complaints about the project received by the researchers must also be referred immediately to the UHEC.

- Withdrawal of Project. If you decide to discontinue your research before its planned completion, you must inform the relevant committee and complete a Final Report form.

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

- Annual Progress Reports. If your project continues for more than 12 months, you are required to submit a Progress Report annually, on or just prior to 12 February. The form is available on the Research Office website. Failure to submit a Progress Report will mean approval for this project will lapse.

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

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

You may log in to ResearchMaster (https://rmenet.latrobe.edu.au) to view your application.

If you have any further questions, please contact the:

UHEC at humanethics@latrobe.edu.au

SHE College Human Ethics Sub-Committee at chesc.she@latrobe.edu.au

ASSC College Human Ethics Sub-Committee at chesc.assc@latrobe.edu.au

LA TROBE UNIVERSITY

University Human Ethics Committee

RESEARCH OFFICE

MEMORANDUM

To: **Professor Kay Crossley, School of Allied Health, College of SHE**

From: **Senior Human Ethics Officer, La Trobe University Human Ethics Committee**

Subject: **Review of Human Ethics Committee Application No. 16-082 Mod 1**

Title: **Validity and reliability of wearable technology during incremental exercise and free-living activity**

Date: **31 July, 2017**

Thank you for submitting your modification request for ethics approval to the La Trobe University Human Ethics Committee (UHEC) for the project referred to above. The UHEC has reviewed and approved the following modification/s which may commence now:

- **Change of title of the study from' Validity and Reliability of wearable technology during incremental exercise' to 'Validity and reliability of wearable technology during incremental exercise and free-living activity'.**
- **Modification to Primary and Secondary Aims.**
- **Data collection to take place over a 14 day period during which participants will wear 2 wrist devices and 1 at the waist (Actigraph) during waking hours, excluding any water based activity or contact sports. Data extraction and analysis will be as established for treadmill data.**
- **Addition of a short activity log that will be emailed to participants.**
- **Alteration to Participant Information Statement.**
- **Invitation to be sent to existing participants to take part in free-living study and recruit participants to take part in free-living study using the current social media resources of the study. Inclusion / exclusion criteria remain unchanged however, the free-living data collection will carry this additional exclusion criteria –"You will be unable to participate in the free-living study if you are unable to wear the devices during your work due to health and safety restrictions".**
- **Change to total recruitment numbers to accommodate recruitment of 40 participants into free-living element of the study. Estimation of 15 additional participants to be recruited to undertake the free-living element of the study.**
- **Extension of project duration to 1 July, 2018.**

- **Addition of Dr Harvi Hart as an investigator**

Please note that your request has been reviewed by a sub-committee of the UHEC to facilitate a decision before the next Committee meeting. This decision will require ratification by the UHEC and it reserves the right to alter conditions of approval or withdraw approval at that time. However, you may commence prior to ratification and you will be notified if the approval status of your project changes.

The following standard conditions apply to your project:

- **Limit of Approval.** Approval is limited strictly to the research proposal as submitted in your application while taking into account any additional conditions advised by the UHEC.

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

- **Adverse Events.** If any unforeseen or adverse events occur, including adverse effects on participants, during the course of the project which may affect the ethical acceptability of the project, the Chief Investigator must immediately notify the UHEC Executive Officer on telephone (03) 9479 1443. Any complaints about the project received by the researchers must also be referred immediately to the UHEC Executive Officer.

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

- **Monitoring.** All projects are subject to monitoring at any time by the UHEC.

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

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

- **Final Report.** A Final Report (see above address) is required within six months of the completion of the project or by **14 June 2018.**

If you have any queries on the information above please e-mail: **humanethics@latrobe.edu.au** or contact me by phone.

Kind regards

Ms Sara Paradowski
Senior Human Ethics Officer
Executive Officer – University Human Ethics Committee

Ethics and Integrity / Research Office
La Trobe University Bundoora, Victoria 3086
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http://www.latrobe.edu.au/researchers/ethics/human-ethics

School of Allied Health
College of Science, Health and Engineering
La Trobe University

Participant Information Statement

Project Title: VALIDITY AND RELIABILITY OF WEARABLE TECHNOLOGY DURING INCREMENTAL EXERCISE AND FREE LIVING ACTIVITY

Investigators:

1. Prof Kay Crossley School of Allied Health. College of Science, Health and Engineering. La Trobe University. k.crossley@latrobe.edu.au

2. Dr Joanne Kemp School of Allied Health. College of Science, Health and Engineering. La Trobe University j.kemp@latrobe.edu.au

3.Dr Ben Dascombe School of Allied Health. College of Science, Health and Engineering. La Trobe University. B.Dascombe@latrobe.edu.au

4. Dr Harvi Hart School of Allied Health. College of Science, Health and Engineering. La Trobe University h.hart@latrobe.edu.au

5, Denise Jones, PhD student, School of Allied Health. College of Science, Health and Engineering. La Trobe University 18772915@students.latrobe.edu.au

We invite you to participate in our research project "Validity and reliability of wearable technology during incremental exercise and free-living activity". We would like to give you some background information on why we think this project is important and on what we would like you to do if you decide to participate.

What is this study about and why is it important?

Physical activity is proving to be one of the most important measures of health and wellbeing. Physical activity trackers, such as the Fitbit Flex™ are becoming increasingly popular and have the potential to collect physical activity data for research. The main aim of this study is assess how accurate and reproducible the data gained from wearable technology is across a range of exercise intensities and during 2 weeks of normal activity, referred to as 'free-living'. This data will be used to inform decisions on the use of these trackers in further studies monitoring the effects of injury upon physical activity.

What does the research involve?

Part 1 - Incremental exercise:

Once screened for eligibility, you will be asked to attend La Trobe University (BS1 224) to undertake a graded exercise test. The total time commitment will be approximately 1hr.

You will need to wear appropriate clothing and footwear that allows you to run comfortably.

For 24 hours prior to attending you will need to abstain from alcohol, caffeine, smoking and high intensity exercise. You should also avoid a heavy meal for at least 3 hours prior to testing.

Before starting the test, your height, body mass and stride length will be recorded. You will be asked to wear 3 Fitbit Flex™ wrist bands throughout the exercise, with one being placed on your right wrist and two on your left . You will also wear a heart rate monitor around your rib cage, two small devices on your shoe ('foot pods') that measures step count and a small waist band mounted activity monitor called an actigraph. As a 'gold standard' assessment of your energy expenditure all air expired will be collected and analysed using a ParvoMedics TrueOne 2400 Metabolic Measurement System. During testing you will wear a nose clip and the air that you breathe will be delivered via a mouth piece. You will be given time at the start of the testing to get used to all the equipment and warm up at a comfortable pace on the treadmill. We can take this time to make any adjustments to the equipment to ensure you are comfortable.

The test you are undertaking is a graded exercise test on a treadmill that will begin at 4 $km \cdot h^{-1}$ with each level lasting 4 minutes in duration. There will be a 1 minute rest between each level. At each level you will be asked

to gradually increase your running speed (2 $km \cdot h^{-1}$ increase for each level). You will always be asked if you are comfortable to progress to the next level and the test will be stopped when you feel you have reached the maximum speed at which you can run. The test will also be stopped if the research team determine that you have reached your maximal running speed that can be performed aerobically.

If you would like to have information on your threshold levels for your own training purposes following the test, this can be achieved by taking a small capillary blood sample during each rest period. This is entirely your choice and we are happy to answer any further questions you may have regarding this.

Part 2 - Free-living:

Once screened for eligibility, an appointment will be made for you to meet with the research team and be provided with two wrist worn devices (Fitbit Flex). You will also be provided with a small waist worn accelerometer called an Actigraph, shown in the picture below.

Before starting the test, your height, body mass, date of birth and ethnicity will be recorded and used to initialise the devices. All 3 devices need to be worn each day for 14 consecutive days. They should be worn during waking hours for all activities other than water-based activities (such as swimming and bathing) and contact sports. All the devices can be removed when sleeping. The two wrist devices will be worn on your non-dominant arm and the Actigraph on a belt just below your waist.

You will be emailed a short activity log to complete at the end of each day to record times when you were unable to wear the devices and any sport activity undertaken. This will take less than 5 minutes to complete.

Why were you chosen for this research?

You can participate in this study if you are aged between 18 and 50 years of age and have no health problems that restrict your physical activity. You will be asked to complete a short health related questionnaire to confirm your fitness to participate. You are not eligible to participate in this study if you: (i) have a physical inability to undergo physical testing procedures; (ii) are not fluent in written and spoken English or (iii) are pregnant, might be pregnant or are breast feeding. You will be unable to participate in the free-living study if you are unable to wear the devices during your work due to health and safety restrictions.

Consenting to participate in the project and withdrawing from the research

Before you can participate in the study you will be asked to read this participant information statement and sign a consent form indicating you have understood what the study is about and that you agree to participate. You have a right to withdraw from further participation at any stage without disadvantages, penalties or adverse consequences. Specifically, this is will not impact upon any relationships with the University or and affiliated clinics/sporting clubs. If you are a student at the university your decision to take part, not to take part or to withdraw will not affect your future grades, assessment or interaction with the university in any way.

<u>You are free to participate in one or both components of the study.</u>

You have the right to withdraw from active participation in the project at any time. You may also request that data arising from your participation is not used in the research project provided that this right is exercised within four weeks of the completion of your participation in the project. You are asked to complete the "Withdrawal of Consent Form" or to notify us, by email or telephone that you wish to withdraw your consent for your data to be used in this research project.

What are the possible risks of participating in this study?

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College of Science, Health and Engineering
La Trobe University

Blood testing – Participation in this element of testing is entirely voluntary and does not affect your ability to undertake the other elements of the study. Blood will be taken from your finger tip which will have been cleaned prior to testing. For each sample a small pin-prick lance will be used. Each lance is sterile with only 1 drop of blood being required for analysis during each rest period. Samples will be taken by a qualified exercise scientist.

Treadmill testing-. You will experience the same level of discomfort that you may normally experience when running. The speeds will always be progressed gradually (2 $km \cdot h^{-1}$ at each level) and levels will only be progressed if you are comfortable and confirm that you wish to continue. The test will be stopped when you feel you have reached the maximum speed at which you wish to run. The test will also be stopped if the research team observed that you have reached your aerobic capacity. Please report to the researcher any undue discomfort or pain experienced during the testing. If the pain or discomfort is deemed to be excessive by yourself or the investigators, testing will cease.

If required, emergency procedures will be used to deal with any medical event that arises during the testing. The physiotherapy departments and on-call security have documented procedures for emergencies. This includes annual St John's ambulance CPR training and appropriate management of fire for all staff.

Free-living - A few users have reported an allergic reaction to the strap of the wrist worn devices. Should you get any irritation of your skin, please stop using the device immediately.
The devices are only splash proof and should not be worn for activities such as swimming, bathing or showering. Certain sports codes and work activities may ban the wearing of devices around the wrist. Please do not wear the devices if any of these restrictions apply.

What are the possible benefits of participating in this study?

There are no direct benefits in completing this study. Your participation will enable us to make informed decisions on how useful the devices will be in future research to monitor physical activity.

From the treadmill testing procedures, you will be provided with information on your VO_2Max (if testing is continued to the level that this is attained) and training threshold levels (if you choose to undertake the blood tests).

What will happen to the results?

The results of this project may appear in journal publications and in conference presentations, but you will not be able to be identified in any of these reports. With your consent, still and video images may be taken during aspects of the testing procedures. These images may be used in future for professional training purposes at Universities, or presentations at conferences related to the testing procedures used in this study. All images will be edited to prevent facial recognition for de-identification purposes. Data may also be used by members of this research team in future projects to compare with results from similar studies relating to the same testing procedures.

Results from the study will be confidential and only accessible by the researchers named above. No-one other than the investigators will have access to the data. No findings that could identify you will be published and access to individual results is restricted to the investigators. All data and results will be handled in a strictly confidential manner, under guidelines set out by the National Health and Medical Research Council. Data will be kept in a password protected computer located at La Trobe University Health Sciences 3 building. Hard copies of questionnaires will be kept in a locked filing cabinet in the office of Prof Kay Crossley (room 508, 5th Floor, Health Sciences 3) at La Trobe University. Data will be stored for at least 5 years after completion of the study in the Health Sciences storage vault, Building 3, level 1.

Furthermore, the data which is collected on you and the results of the experiment will be made available to you upon request. This may entail a mailing of results to your home residence, or if you prefer, a discussion with one of the investigators in person.

Funding

Funding for this project has been kindly provided by the National Health and Medical Research Council of Australia (NHMRC). Denise Jones is supported by an Australian Government Research Training Scholarship for her PhD studies.

School of Allied Health
College of Science, Health and Engineering
La Trobe University

Who can I contact if I have any questions?

Questions concerning the procedure and/or rationale used in this investigation are welcome at any time. Please ask for clarification of any point, which you feel, is not explained to your satisfaction. Your initial contact is the person conducting the experiment (Dr Ben Dascombe, 03 53279587 or b.dascome@latrobe.edu.au).

Thank you

Prof Kay Crossley, Dr Joanne Kemp, Dr Ben Dascombe, Denise Jones

If you have any complaints or concerns about your participation in the study that the researcher has not been able to answer to your satisfaction, you may contact the Senior Human Ethics Officer, Ethics and Integrity, Research Office, La Trobe University, Victoria, 3086 (P: 03 9479 1443, E: humanethics@latrobe.edu.au) . Please quote the application reference number HEC16-082.

School of Allied Health
College of Science, Health and Engineering
La Trobe University

La Trobe University Human Ethics Committee Participant Consent Form

Project Title: VALIDITY AND RELIABILITY OF THE FITBIT FLEX™.

Investigator no.1 **Prof Kay Crossley**

Investigator no.2 **Dr Ben Dascombe**

Investigator no.3 **Dr Joanne Kemp**

I _____ have read and understood the **participant information statement and consent form**, and any questions I have asked have been answered to my satisfaction. I understand that even though I agree to be involved in this project, I can withdraw from the study at any time, up to four weeks following the completion of my participation in the research. Further, in withdrawing from the study, I can request that no information from my involvement be used. I agree that research data provided by me or with my permission during the project may be included in a thesis, presented at conferences and published in journals on the condition that neither my name nor any other identifying information is used.

	Yes	No
I am willing to have photographs and/ or videos taken during the testing session and consent for these images or videos to be used solely for education and research purposes at physiotherapy schools at other universities in Australia and when presentations are made at conferences / workshops in National and International Settings.	☐	☐

Last Name: Given Name: **(BLOCK LETTERS)**

DOB: Age: Contact Phone number:

Address:

Signature: Date:

Investigator name (BLOCK LETTERS):

Signature: Date:

Supervisor: Date:

Name and phone number of contact person in case of an emergency:

Name: Phone:

Subject Signature: Date:

APPENDIX 4: COPIES OF ETHICAL APPROVAL DOCUMENTS, PATIENT INFORMATION STATEMENT AND INFORMED CONSENT, FEMOROACETABULAR IMPINGEMENT AND HIP OSTEOARTHRITIS COHORT (FORCE)

LA TROBE UNIVERSITY

University Human Ethics Committee

RESEARCH OFFICE

MEMORANDUM

To: **Dr Kay Crossley, School of Allied Health, College of Science, Health and Engineering**

From: **Senior Human Ethics Officer, La Trobe University Human Ethics Committee**

Subject: **Review of Human Ethics Committee Application No. 15-019**

Title: **Femoroacetabular impingement and early osteoarthritis**

Date: **4 June 2015**

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

The project has been approved from the date of this letter until 1 June 2020.

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

The following standard conditions apply to your project:

- **Limit of Approval.** Approval is limited strictly to the research proposal as submitted in your application while taking into account any additional conditions advised by the UHEC.

- **Variation to Project.** Any subsequent variations or modifications you wish to make to your project must be formally notified to the UHEC for approval in advance of these modifications being introduced into the project. This can be done using the appropriate form: *Modification to Project – Human Ethics* which is available on the Human Ethics website at http://www.latrobe.edu.au/researchers/ethics/human-ethics If the UHEC

considers that the proposed changes are significant, you may be required to submit a new application form for approval of the revised project.

- **Adverse Events.** If any unforeseen or adverse events occur, including adverse effects on participants, during the course of the project which may affect the ethical acceptability of the project, the Chief Investigator must immediately notify the UHEC Executive Officer. An *Adverse Event Form – Human Ethics* is available at the Research Services website (see above address). Any complaints about the project received by the researchers must also be referred immediately to the UHEC Executive Officer.

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

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

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

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

- **Final Report.** A Final Report (see above address) is required within six months of the completion of the project or by **1 December 2020.**

If you have any queries on the information above or require further clarification please email: **humanethics@latrobe.edu.au** or contact me by phone.

On behalf of the University Human Ethics Committee, best wishes with your research!

Kind regards,

Ms Sara Paradowski
Senior Human Ethics Officer
Executive Officer – University Human Ethics Committee
Ethics and Integrity / Research Office
La Trobe University Bundoora, Victoria 3086
P: (03) 9479 – 1443 / F: (03) 9479 - 1464
http://www.latrobe.edu.au/researchers/ethics/human-ethics

LA TROBE UNIVERSITY

University Human Ethics Committee

RESEARCH OFFICE

MEMORANDUM

To: **Professor Kay Crossley, School of Allied Health, College of SHE**

From: **Senior Human Ethics Officer, La Trobe University Human Ethics Committee**

Subject: **Review of Human Ethics Committee Application No. 15-019 Mod 4**

Title: **Femoroacetabular impingement and early osteoarthritis**

Date: **30 May 2016**

Thank you for submitting your modification request for ethics approval to the La Trobe University Human Ethics Committee (UHEC) for the project referred to above. The UHEC has reviewed and approved the following modification/s which may commence now:

- **Utilising the Fitbit Flex™ (FBF) as a quantitative measure of physical activity.**

Please note that your request has been reviewed by a sub-committee of the UHEC to facilitate a decision before the next Committee meeting. This decision will require ratification by the UHEC and it reserves the right to alter conditions of approval or withdraw approval at that time. However, you may commence prior to ratification and you will be notified if the approval status of your project changes.

The following standard conditions apply to your project:

- **Limit of Approval.** Approval is limited strictly to the research proposal as submitted in your application while taking into account any additional conditions advised by the UHEC.

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

- **Adverse Events.** If any unforeseen or adverse events occur, including adverse effects on participants, during the course of the project which may affect the ethical acceptability of the project, the Chief Investigator must immediately notify the UHEC Executive Officer on telephone (03) 9479 1443. Any

complaints about the project received by the researchers must also be referred immediately to the UHEC Executive Officer.

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

- **Monitoring.** All projects are subject to monitoring at any time by the UHEC.

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

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

- **Final Report.** A Final Report (see above address) is required within six months of the completion of the project or by **1 December 2020.**

If you have any queries on the information above please e-mail: **humanethics@latrobe.edu.au** or contact me by phone.

Kind regards

Ms Sara Paradowski
Senior Human Ethics Officer
Executive Officer – University Human Ethics Committee
Ethics and Integrity / Research Office
La Trobe University Bundoora, Victoria 3086
P: (03) 9479 – 1443 F: (03) 9479 - 1464
http://www.latrobe.edu.au/researchers/ethics/human-ethics

School of Allied Health
College of Science, Health and Engineering
La Trobe University

Participant Information Statement

Project Title: **FEMOROACETABULAR IMPINGEMENT AND EARLY OSTEOARTHRITIS.**

SUPPLEMENTARY INFORMATION FOR THE USE OF FITBIT FLEX™ TO COLLECT PHYSICAL ACTIVITY DATA.

Investigators:

1. Prof Kay Crossley School of Allied Health. College of Science, Health and Engineering. La Trobe University. k.crossley@latrobe.edu.au

2. Dr Adam Semciw School of Health and Rehabilitation Sciences, The University of Queensland. A.semciw@uq.edu.au

3. Dr Joanne Kemp The Australian Centre for Research into Injury in Sport and its Prevention, Federation University, j.kemp@federation.edu.au

4. Prof Marcus Pandy Melbourne School of Engineering, The University of Melbourne, pandym@uunimelb.edu.au

5. Dr Anthony Schache Melbourne School of Engineering, The University of Melbourne a.schache@unimelb.edu.au

6. Dr Ben Dascombe School of Allied Health. College of Science, Health and Engineering. La Trobe University. B.Dascombe@latrobe.edu.au

We invite you to participate in an element of this research project that utilises the Fitbit Flex™ to gather information on physical activity. Please view the information below to help you to decide if you wish to participate. We are happy to answer any further questions you may have.

Why include Fitbit™ activity data in this study?

The Fitbit Flex™ is a wrist worn device that tracks physical activity. Using the Fitbit™ provides us with the opportunity to observe a direct measure of physical activity to supplement the broader picture of activity participation that we gain from the questionnaires you complete. Physical activity is an important measure of health and wellbeing which may be influenced by femoroacetebular impingement (FAI).

The primary aim is to evaluate changes in physical activity over 2 years. This knowledge may help to develop targeted intervention strategies for managing this condition in the future.

Physical activity trackers, such as the Fitbit Flex™ are becoming increasingly popular. A secondary aim is to assess the feasibility for their use in a long term study such as this. Consequently we will also be gathering data on your experience of using the tracker within this context.

Can I take part?

You are eligible to take part in this section of the study if:

1. You are able to wear the Fitbit™ every day.
2. You have access to a computer so that the information from the Fitbit™ can be uploaded.

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La Trobe University

What does taking part involve?

You will be given a Fitbit Flex™ to wear on a daily basis. It is important that you are able to wear the device every day on the wrist of your dominant hand. You will also need access to a computer so that you can set up and upload the information from the device. You will be given a password and email address that will be linked to the device you are given.

Once the device is set up you will have access to your own Fitbit™ interface (called a dashboard), the same as any other user. This interface is accessible only by yourself (although you do have the option to share with your friends should you chose to do so).

Once the Fitbit™ is linked to your computer, the information from the Fitbit™ will be automatically synched to the computer via a USB dongle.

How is the data collected?

When data is uploaded from your Fitbit, it is stored by Fitbit™ on an online server. The information collected by the research team will be gathered from that server using a program that will remotely log in and download the data. The research team **will not** need to log into your account through the Fitbit™ web page and will not access the personal dashboard and information that you set up.

Should any eventuality occur that would require the research team to log into the website you will be contacted for consent before proceeding.

What information is being collected and how is it stored?

Activity (in the form of number of steps taken) and sleep (number of hours) will be downloaded for each day of the trial. The activity data will be downloaded in 15 min periods throughout the day, and a summary of time spent in various activity levels will be generated.
Your data will be confidential and only accessible by the researchers named above. No-one other than the investigators will have access to the data. No findings that could identify you will be published and access to individual results is restricted to the investigators. All data and results will be handled in a strictly confidential manner, under guidelines set out by the National Health and Medical Research Council. Data will be kept in a password protected computer located at La Trobe University Health Sciences 3 building. Data will be stored for at least 5 years after completion of the study in the Health Sciences storage vault, Building 3, level 1.

What if I have my own Fitbit™?

If you are happy to provide us with the login details linked to your Fitbit™, the information can be collected in the same way, with the same provisions to protect your personal data.

Can I change my mind?

We realise that this is a long term commitment and that circumstances change. If at any point you would like to withdraw from this part of the study you are free to do so. You have a right to withdraw from further participation in this element of the study at any stage without disadvantages, penalties or adverse consequences. This will not impact upon your ongoing participation in other areas of the study. Your choice to participate, not participate or to withdraw from using the Fitbit™ will not affect your future participation.

How do I withdraw?

Please notify us, by email or telephone that you no longer wish to use the Fitbit™. We would ask that you complete the “FBF - Withdrawal of Consent Form” to confirm the inclusion or exclusion of previously gathered data from the study.

School of Allied Health
College of Science, Health and Engineering
La Trobe University

We will supply you with a stamped self-addressed envelope in which to return the device.

What are the possible benefits?
The Fitbit Flex™ will allow you to track your own activity data and utilise all the features of the device (http://www.fitbit™ .com/au/flex). Once the study is completed, the Fitbit Flex™ device is yours to keep.
The information we gain from the study will be used to direct better treatments in future for people with this hip condition.

What are the possible risks?
A few users have reported an allergic reaction to the strap of the Fitbit™. Should you get any irritation of your skin, please stop using the device immediately. We will send you a stamped self-addressed envelope to return the Fitbit™ to us.
The Fitbit™ is only splash proof and should not be worn for activities such as swimming, bathing or showering.
Certain sports codes and work activities may ban the wearing of devices around the wrist. Please do not wear the Fitbit™ if any of these restrictions apply.

What will happen to the results?
The results of this project will appear in journal publications and in conference presentations, but you will not be able to be identified in any of these reports. Data may also be used by members of this research team in future projects to compare with results from similar studies relating to the same testing procedures.

Who can I contact if I have any questions?
Questions concerning the procedure and/or rationale used in this investigation are welcome at any time. Please ask for clarification of any point that has not been explained to your satisfaction. Your initial contact is the person conducting the experiment (Professor Kay Crossley, 9479 3902 or k.crossley@latrobe.edu.au).

Complaints
If you have any complaints or queries that the researcher has not been able to answer to your satisfaction, you may contact the Ethics Liaison Officer, Faculty of Health Sciences Ethics Committee, La Trobe University, Victoria, 3086, (ph: 94791443, email: humanethics@latrobe.edu.au). FHEC reference number 15-019

Thank you

Prof Kay Crossley, Dr Adam Semciw, Dr Joanne Kemp, Prof Marcus Pandy, Dr Anthony Schache, Dr Ben Dascombe

School of Allied Health
College of Science, Health and Engineering
La Trobe University

La Trobe University Human Ethics Committee Participant Consent Form

Project Title: FEMOROACETABULAR IMPINGEMENT AND EARLY OSTEOARTHRITIS – Use of the Fitbit Flex™

Investigators:

1. **Prof Kay Crossley**
2. **Dr Adam Semciw**
3. **Dr Joanne Kemp**
4. **Prof Marcus Pandy**
5. **Dr Anthony Schache**
6. **Dr Ben Dascombe**

I _____ have read and understood the **participant information statement regarding the use of the Fitbit Flex™**, and any questions I have asked have been answered to my satisfaction. I understand that even though I agree to be involved in this part of the study, I can withdraw from using the device at any time. Further, in withdrawing from this part of the study, I can request that no information from my involvement be used. I agree that research data provided by me or with my permission during the project may be included in a thesis, presented at conferences and published in journals on the condition that neither my name nor any other identifying information is used.

Last Name:	Given Name:
Signature:	Date:
Witness name:	

APPENDIX 5: COPIES OF ETHICAL APPROVAL DOCUMENTS, PATIENT INFORMATION STATEMENT AND INFORMED CONSENT, PHYSIOTHERAPY FOR FEMOROACETABULAR IMPINGEMENT REHABILITATION STUDY (PHYSIOFIRST)

HEC17-080 (Pending - UHEC) - Application finalised as Approved

ResearchMasterEthics@latrobe.edu.au

Thu 21/09/2017 10:02 AM

To: Joanne Kemp <J.Kemp@latrobe.edu.au>;

Cc: Denise Jones <D.Jones@latrobe.edu.au>; Anthony Schache <A.Schache@latrobe.edu.au>; Kay Crossley <K.Crossley@latrobe.edu.au>; Sally Coburn <S.Coburn@latrobe.edu.au>; ResearchMasterEthics <ResearchMasterEthics@latrobe.edu.au>;

** This is an automatically generated email, please do not reply. Contact details are listed below.**

Dear Joanne Kemp,

The following project has been assessed as complying with the National Statement on Ethical Conduct in Human Research. I am pleased to advise that your project has been granted ethics approval and you may commence the study.

Application ID: HEC17-080
Application Status/Committee: University Human Ethics Committee

Project Title: The physiotherapy for Femoroacetabular Impingement Rehabilitation STudy (PhysioFIRST): A participant and assessor-blinded randomised controlled trial of physiotherapy for hip impingement.

Chief Investigator: Joanne Kemp

Other Investigators: Kay Crossley, Sally Coburn, Denise Jones, Anthony Schache, Dr Steven McPhail

Date of Approval: 21/09/2017
Date of Ethics Approval Expiry: 31/08/2021

The following standard conditions apply to your project:

- Limit of Approval. Approval is limited strictly to the research proposal as submitted in your application.

- Variation to Project. Any subsequent variations or modifications you wish to make to your project must be formally notified for approval in advance of these modifications being introduced into the project.

- Adverse Events. If any unforeseen or adverse events occur the Chief Investigator must notify the UHEC immediately. Any complaints about the project received by the researchers must also be referred immediately to the UHEC.

- Withdrawal of Project. If you decide to discontinue your research before its planned completion, you must inform the relevant committee and complete a Final Report form.

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

- Annual Progress Reports. If your project continues for more than 12 months, you are required to submit a Progress Report annually, on or just prior to 12 February. The form is available on the Research Office website. Failure to submit a Progress Report will mean approval for this project will lapse.

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

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

You may log in to ResearchMaster (https://rmenet.latrobe.edu.au) to view your application.

If you have any further questions, please contact the:
UHEC at humanethics@latrobe.edu.au
SHE College Human Ethics Sub-Committee at chesc.she@latrobe.edu.au
ASSC College Human Ethics Sub-Committee at chesc.assc@latrobe.edu.au

Research Office

To	Joanne Kemp
From	University Human Ethics Committee
HEC Number	HEC17-080
Project title	The physiotherapy for Femoroacetabular Impingement Rehabilitation STudy (PhysioFIRST): A participant and assessor-blinded randomised controlled trial of physiotherapy for hip impingement
Subject	Modification request received from Joanne Kemp dated 29.01.2019 re: (1) Additional of biometric testing and MRI scans in a subset of participants; and (2) Addition of Benjamin Mentiplay to the project as associate investigator.
Date	4 February 2019

The modification to this project submitted above was **approved** by the **University Human Ethics Committee**.

If this project is a multicentre project you must forward a copy of this letter to all Investigators at other sites for their records.

Please note that all requirements and conditions of the original ethical approval for this project still apply.

Should you require any further information, please contact the Human Research Ethics Team on:
T: +61 3 9479 1443| E: humanethics@latrobe.edu.au.

La Trobe University wishes you every continued success in your research.

Warm regards,

David Finlay
Chair, University Human Ethics Committee

La Trobe Sports and Exercise Medicine Research Centre

LTU ethics approval number HEC17-080

The physiotherapy for Femoroacetabular Impingement Rehabilitation STudy (PhysioFIRST): A participant and assessor-blinded randomised controlled trial of physiotherapy for hip impingement.

Investigators: Dr Joanne Kemp, Sally Coburn, Denise Jones, Dr Anthony Schache, Dr Benjamin Mentiplay
Associate Professor Dr Steven McPhail, Professor Kay Crossley

Participant Information Statement

We invite you to participate in our project: "The physiotherapy for Femoroacetabular Impingement Rehabilitation STudy (PhysioFIRST): A participant and assessor-blinded randomised controlled trial of physiotherapy to reduce pain and improve function for hip impingement."

We would like to give you some background information to explain why we think this project is important and describe what we would like you to do if you decide to join us in this research.

What is the purpose of this study?

Femoroacetabular (hip) impingement is a painful condition that commonly affects healthy active younger adults. It can limit their ability to continue playing sport and perform normal daily activities. It can be related to extra bone formation at the hip joint known as a cam deformity. Physiotherapy is one treatment people may use to reduce their symptoms and improve their function. We would like to compare the benefits of two different physiotherapy treatments to find the best way to manage this condition. Funding for this project has been provided by La Trobe Sports and Exercise Medicine Research Centre at La Trobe University, an Arthritis Australia State/Territory Affiliate grant and a National Health and Medical Research Council Early Career Fellowship grant to Dr Kemp.

Who can participate in this study?

- People aged 18 to 50 years
- People with hip or groin pain aggravated by activity some of the time for more than 6 weeks
- People with signs of hip impingement when the hip is tested by a physiotherapist
- People with x-rays showing you have a 'cam deformity'

You are not eligible to participate in this study if:

- You cannot understand written or spoken English
- You have had physiotherapy in the past three months
- You have had hip surgery before
- You are not able to commit to a
    - **12-week physiotherapy program**
    - **a subsequent 12-week gym program, where you attend three times per week**
    - **baseline** (beginning) physical assessment
    - **follow-up** (24 weeks - after all treatments) physical assessment

- You are unable to have an x-ray of your pelvis (both hips at once) eg. You are pregnant or breastfeeding/unwilling

What does the project involve?

1. *Screening assessment (10 mins)*

You will be asked some questions about your hip over the phone to ensure you are eligible for the study. You will be asked to provide details of where any previous x-rays of your sore hip were taken for assessment of the digital copy to see if you have a 'cam deformity'. If you don't have x-rays we will organise a free hip (pelvic) x-ray for you at an x-ray clinic convenient to you (Imaging at Olympic Park, 60 Olympic Blvd, Melbourne or at Lake Imaging, Howitt St, Ballarat) if you are willing and able. The x-ray assessment will take about 30 minutes.

2. *Physical testing of your hip and questionnaires – Baseline (45 mins)*

If your movement tests and x-rays indicate you are eligible, we will ask you to attend an appointment at a mutually convenient time at La Trobe University, Melbourne, or at Lake Health Group, Ballarat, to undergo baseline measurement of your hip movements and strength. These baseline tests will take about half an hour.

Following the assessment we will ask you to complete several questionnaires online, and will be provided with instructions for access to the website. If you prefer you may complete a paper version of the questionnaires instead. The questionnaires will ask you questions about your hip/groin pain, other hip-related symptoms and your levels of physical activity and take about 15 minutes to complete.

3. *Biomechanical assessment of your movement (60 minutes)*

If you are willing to, we will undergo biomechanical assessment of your movement patterns after your physical testing described above. This testing will occur at La Trobe University, Melbourne. You will be asked to wear shorts (either you can bring some or we will provide you will shorts) and a singlet whilst you perform a series of tests including walking, running, squatting, jumping, and going up/down stairs. Reflective skin markers will be placed over your upper and lower body. Testing should take no longer than 60 minutes to complete. Participation in this section of the research is optional.

4. *Collection of activity data using Fitbit Flex 2™*

If you are willing to participate in this portion of the research, you will be given a Fitbit flex™ to wear on a daily basis for 14 consecutive days. It is important that you are able to wear the device every day on the wrist of your dominant hand. You will also need access to a computer so that you can set up and upload the information from the device. You will be given a password and email address that will be linked to the device you are given. Participation in this section of the research is optional.

Once the device is set up you will have access to your own Fitbit™ interface (called a dashboard), the same as any other user. This interface is accessible only by yourself (although you do have the option to share with your friends should you chose to do so).

Once the Fitbit™ is linked to your computer, the information from the Fitbit™ will be automatically synched to the computer via a USB dongle.

When data is uploaded from your Fitbit™, it is stored by Fitbit™ on an online server. The information collected by the research team will be gathered from that server using a program that will remotely log in and download the data. The research team will not need to log into your account through the Fitbit™ web page and will not access the personal dashboard and information that you set up.

5. *A free MRI of your hip (45 mins)*

If you are willing to participate in this portion of the research, we will investigate your hip joint structure in detail via a magnetic resonance imaging (MRI) scan at Imaging at Olympic Park, 60 Olympic Blvd, Melbourne. Parking is free and parking instructions are on the referral. The MRI will take place prior to the intervention period as well as after to examine any changes in your hip joint. You may not be able to participate in this section of the testing if you have a pacemaker, metal implants, or claustrophobia. Participation in this section of the research is optional.

6. *Physiotherapy treatment (12 weeks)*

After the first assessment and completion of the questionnaires, you will be randomly allocated to one of the physiotherapy treatment groups. Both treatments are used regularly by physiotherapists. You will then be asked to attend one of three physiotherapy clinics in Melbourne (or at Lake Health Group in Ballarat). Your treatment will comprise two phases which is provided free of charge and includes physiotherapy treatments and a 3 month gym membership.

In Phase 1, you will receive 6 free physiotherapy treatments over a period of twelve weeks. Each fortnightly treatment will last 30 minutes and will be performed by an experienced and project-trained physiotherapist. You will also be asked to perform a gym-based exercise program once per week in the gym at the same clinic. There are also exercises to complete at home twice per week. All treatments and any use of gym equipment will be provided at no cost to you.

7. *Gym membership (12 weeks)*

In Phase 2, you will receive a free 3-month gym membership and continue the exercise program you received in Phase 1 three times per week. You will receive a further three free physiotherapist reviews to continue to monitor your progress.

8. *Physical testing of your hip and questionnaires – Follow-up (45 mins)*

You will then return to La Trobe University (or Lake Health Group, Ballarat) for a final physical assessment. This will take approximately the same amount of time as the first assessment (about 45 minutes) and will also include biomechanics assessment if you participated in this before the intervention (about 60 minutes). The examiner physiotherapist will not know which treatment you have received. We ask you not to discuss your treatment with the examiner. We will also provide the same follow-up questionnaires for you to complete again (15 minutes), on paper, or online, and will ask you some questions about your experience of the project.

You will not receive any payment for your participation, however you will have free x-ray (and MRI if applicable) and assessment of your hip problem and free comprehensive physiotherapy if you are eligible and choose to participate.

We will also give you a $100 gift voucher for attending the final 6-month assessment of your hip at La Trobe University, as your assessment provides data critical to the success of our study. You may also ask for a copy of your assessment results.

We also ask that if you are considering another treatment for your hip or another musculoskeletal condition, you discuss the impact this might have on the study with the project leader, Dr Joanne Kemp.

Are there any potential side-effects?

The impingement and movement tests represent usual examination by a physiotherapist. You may experience a small amount of discomfort in the joints or tiredness in the muscles during the movement

and strength testing and interventions. Please report any undue discomfort or pain experienced during the testing. If the pain or discomfort is deemed to be excessive by yourself or the examiner, testing or treatment will cease.

If you have not already had a hip xray and require one to determine if you may participate, you will be exposed to a very small amount of radiation. As part of everyday living, everyone is exposed to naturally occurring background radiation and receives a dose of about 2 millisieverts (mSv) each year. The effective dose from this study is about 0.32 mSv. At this dose level, no harmful effects of radiation have been demonstrated as any effect is too small to measure. The risk is believed to be very low. If you decide to participate in the MRI scans, there is no further exposure to radiation with MRI.

If required, emergency procedures will be used to deal with any medical event that arises during testing or physiotherapy treatments. La Trobe University and participating physiotherapy clinics and gymnasiums have documented procedures for emergencies. This includes annual first aid and CPR training and appropriate management of fire for all staff.

What if I have any concerns during the study?

This study is funded La Trobe Sports and Exercise Medicine Research Centre at La Trobe University, Bundoora, Arthritis Australia and National Health and Medical Research Council fellowship grant to Dr Kemp. This study adheres to the La Trobe University Human Ethics Guidelines and National Statement on Ethical Conduct in Human Research. Whilst you are free to discuss your initial participation in this study with the project coordinator (Sally Coburn ph: 0408 761 237), you may want to talk an officer of the University not involved with the study. If so, you may contact the Ethics Manager, Heidi Gaulke on ph: (03) 9479 1443. If you choose to participate, you are free to call the project chief investigator with any queries following the baseline assessment of your hip (Dr Joanne Kemp ph: 0484 776 536)

Can I withdraw from the study if I wish?

Your participation in the study is voluntary. If you do not wish to take part you are under no obligation to do so. If you decide to take part and later change your mind, you are free to withdraw from the study at any stage. You may also withdraw any unprocessed data previously supplied by you.

If you are a student of La Trobe University, your decision whether to take part or not to take part, or to withdraw, will not affect your affiliation with the university in any way.

If you are a patient of any of the investigators or project physiotherapists, your decision whether to take part or not to take part, or to withdraw, will not affect your relationship with the physiotherapy clinic or your future physiotherapy management in any way.

Will my details be kept confidential?

Our procedures require allocation of a code number to identify you and any data associated with your participation. This assures your anonymity as your name will not be used. You will be videoed performing a single leg squat but will be de-identified for analysis. No findings that identify you will be published and access to individual results is restricted to the investigators. Coded data will be stored for at least 5 years. All data and results will be handled in a strictly confidential manner, under guidelines set out by the National Health and Medical Research Council. The chief investigator is responsible for maintaining this confidentiality. This project is subject to the requirements of the La Trobe University Human Ethics Guidelines. However, you must be aware that there are legal limitations to data confidentiality.

What will happen to the results of the study?

Summaries of the study results will be sent to participants, if requested on the consent form. It is possible that results from this study will be presented at a local, national or international conference, or published in a peer reviewed journal. Results may also be used for teaching purposes and web-based translational material. All results are **de-identified**.

How do I get more information?

You should ask for any information you want. If you would like more information about the study, or if there is any matter that concerns you, either now or in the future, do not hesitate to ask one of the investigators or project coordinator. Before deciding whether or not you should take part you may wish to discuss the matter with a relative or friend or with your local doctor. You should feel free to do this. A newsletter will be sent to update you during the project. A project summary will be available, on request via email/post at the conclusion of the study and will include no identifiable information.

About the investigators:

Prof Kay Crossley is a sports physiotherapist and professor at La Trobe Sports and Exercise Medicine Research Centre at La Trobe University, Bundoora.

Dr Joanne Kemp is a sports physiotherapist and post-doctoral researcher at La Trobe Sports and Exercise Medicine Research Centre at La Trobe University, Bundoora.

Sally Coburn is a physiotherapist and research assistant at La Trobe Sports and Exercise Medicine Research Centre at La Trobe University, Bundoora.

Denise Jones is a physiotherapist and research assistant at La Trobe Sports and Exercise Medicine Research Centre at La Trobe University, Bundoora.

Dr Anthony Schache is a physiotherapist and senior research fellow at La Trobe Sports and Exercise Medicine Research Centre at La Trobe University, Bundoora.

Dr Benjamin Mentiplay is an exercise scientist and researcher at La Trobe Sports and Exercise Medicine Research Centre at La Trobe University, Bundoora.

A/Prof Steven McPhail is a health economist at University of Queensland

Contacts:

Enquiries and eligibility:

Sally Coburn

Mob: 0484 761 237

Email: s.coburn@latrobe.edu.au.

If you have commenced participation:

Dr Joanne Kemp

Email: j.kemp@latrobe.edu.au

Mob: 0484 776 536

Participant Code: PF ___ ___ ___

La Trobe Sports and Exercise Medicine Research Centre

Consent form for persons participating in research projects

LTU ethics approval number HEC17-080

The physiotherapy for Femoroacetabular Impingement Rehabilitation STudy (PhysioFIRST): A participant and assessor-blinded randomised controlled trial of physiotherapy for hip impingement.

Investigators: Dr Joanne Kemp, Sally Coburn, Denise Jones, Dr Anthony Schache, Dr Benjamin Mentiplay
Associate Professor Dr Steven McPhail, Professor Kay Crossley

I, _____, have read and understood the **participant information statement and consent form**, and any questions I have asked have been answered to my satisfaction. I understand that even though I agree to be involved in this project, I can withdraw from the study at any time, up to four weeks following the completion of my participation in the research. Further, in withdrawing from the study, I can request that no information from my involvement be used. I agree that research data provided by me or with my permission during the project may be included in a thesis, presented at conferences and published in journals on the condition that neither my name nor any other identifying information is used.

I consent to my data being included in other research projects. I acknowledge that my data will be coded, but can be potentially identified.	Yes ☐	No ☐
I consent to my single leg squat test being videoed. I acknowledge that any video data will be de-identified.	Yes ☐	No ☐
I understand my participation will not affect my current or future staff/student affiliation/physiotherapy management with:	Yes ☐	No ☐

_____

I consent to be involved in the additional testing of physical activity using the Fitbit device	Yes ☐	No ☐
I consent to be involved in the additional testing of my movement patterns through biomechanical assessment	Yes ☐	No ☐
I consent to be involved in the additional testing of hip joint structure via Magnetic Resonance Imaging (MRI) scans	Yes ☐	No ☐
I wish to have a have a summary report sent to me at the conclusion of my participation in this project.	Yes ☐	No ☐

Participant Code: PF ___ ___ ___

Last Name:		Given Name:
DOB:	Age:	Contact Phone number:
Address:		
Signature:		Date:
Witness name:		Date:
Investigator:		Date:

Name and phone number of contact person in case of an emergency:

Name:	Phone:
Family Doctor:	Phone:

APPENDIX 6: COPIES OF ETHICAL APPROVAL DOCUMENTS, PATIENT INFORMATION STATEMENT AND INFORMED CONSENT, HIP ARTHROSCOPY PROSPECTIVE STUDY

LA TROBE UNIVERSITY

University Human Ethics Committee

RESEARCH OFFICE

MEMORANDUM

To: **Dr Joanne Kemp, School of Allied Health, College of SHE**

From: **Senior Human Ethics Officer, La Trobe University Human Ethics Committee**

Subject: **Review of Human Ethics Committee Application No. 16-137**

Title: **Risk factors for early hip osteoarthritis: A longitudinal cohort study**

Date: **1 December 2016**

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

The project has been approved from the date of this letter until 31 December 2018

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

The following standard conditions apply to your project:

- **Limit of Approval.** Approval is limited strictly to the research proposal as submitted in your application while taking into account any additional conditions advised by the UHEC.

- **Variation to Project.** Any subsequent variations or modifications you wish to make to your project must be formally notified to the UHEC for approval in advance of these modifications being introduced into the project. This can be done using the appropriate form: *Modification to Project – Human Ethics* which is available on the Human Ethics website at http://www.latrobe.edu.au/researchers/ethics/human-ethics If the UHEC

considers that the proposed changes are significant, you may be required to submit a new application form for approval of the revised project.

- **Adverse Events.** If any unforeseen or adverse events occur, including adverse effects on participants, during the course of the project which may affect the ethical acceptability of the project, the Chief Investigator must immediately notify the Senior Human Ethics Officer. An *Adverse Event Form – Human Ethics* is available at the Research Office website (see above address). Any complaints about the project received by the researchers must also be referred immediately to the Senior Human Ethics Officer.

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

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

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

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

- **Final Report.** A Final Report (see above address) is required within six months of the completion of the project or by **30 June 2019.**

If you have any queries on the information above or require further clarification please email: **humanethics@latrobe.edu.au** or contact me by phone.

On behalf of the University Human Ethics Committee, best wishes with your research!

Kind regards,

Ms Sara Paradowski
Senior Human Ethics Officer
Executive Officer – University Human Ethics Committee
Ethics and Integrity / Research Office
La Trobe University Bundoora, Victoria 3086
P: (03) 9479 – 1443 / F: (03) 9479 - 1464
http://www.latrobe.edu.au/researchers/ethics/human-ethics

LA TROBE UNIVERSITY

University Human Ethics Committee

RESEARCH OFFICE

MEMORANDUM

To: **Dr Joanne Kemp, School of Allied Health, College of SHE**

From: **Senior Human Ethics Officer, La Trobe University Human Ethics Committee**

Subject: **Review of Human Ethics Committee Application No. 16-137 Mod 1**

Title: **Risk factors for early hip osteoarthritis: A longitudinal cohort study**

Date: **13 March 2017**

Thank you for submitting your modification request for ethics approval to the La Trobe University Human Ethics Committee (UHEC) for the project referred to above. The UHEC has reviewed and approved the following modification/s which may commence now:

- **An additional separate appointment with participants to set up and familiarize them with the Fitbit flex device**
- **Specified time periods for data collection at initial set up, 6 weeks, 3 months, 6 months and 1 year post operatively**
- **Export data from the Fitbit website as a spreadsheet on specified dates only**
- **Amendment to the Participant Information Statement to include changes**

Please note that your request has been reviewed by a sub-committee of the UHEC to facilitate a decision before the next Committee meeting. This decision will require ratification by the UHEC and it reserves the right to alter conditions of approval or withdraw approval at that time. However, you may commence prior to ratification and you will be notified if the approval status of your project changes.

The following standard conditions apply to your project:

- **Limit of Approval.** Approval is limited strictly to the research proposal as submitted in your application while taking into account any additional conditions advised by the UHEC.

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

application form for approval of the revised project.

- **Adverse Events.** If any unforeseen or adverse events occur, including adverse effects on participants, during the course of the project which may affect the ethical acceptability of the project, the Chief Investigator must immediately notify the UHEC Executive Officer on telephone (03) 9479 1443. Any complaints about the project received by the researchers must also be referred immediately to the UHEC Executive Officer.

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

- **Monitoring.** All projects are subject to monitoring at any time by the UHEC.

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

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

- **Final Report.** A Final Report (see above address) is required within six months of the completion of the project or by **30 June 2019.**

If you have any queries on the information above please e-mail: **humanethics@latrobe.edu.au** or contact me by phone.

Kind regards

Ms Sara Paradowski
Senior Human Ethics Officer
Executive Officer – University Human Ethics Committee
Ethics and Integrity / Research Office
La Trobe University Bundoora, Victoria 3086
P: (03) 9479 – 1443 F: (03) 9479 - 1464
http://www.latrobe.edu.au/researchers/ethics/human-ethics

Research Office

To	Joanne Kemp
From	University Human Ethics Committee
HEC Number	HEC16-137
Project title	Risk factors for early hip osteoarthritis: A longitudinal cohort study
Subject	Modification request received from Joanne Kemp dated 18.07.2018 re: (1) Addition of Physical and Psychological Rediness scale (2) Addition of Email inviting to complete the scale for RSI healthy controls version dated 18.07.2018 (3) Updated RSI Controls PICF version dated 18.07.2018
Date	19 July 2018

The modification to this project submitted above was **approved** by the **University Human Ethics Committee**.

If this project is a multicentre project you must forward a copy of this letter to all Investigators at other sites for their records.

Please note that all requirements and conditions of the original ethical approval for this project still apply.

Should you require any further information, please contact the Human Research Ethics Team on:
T: +61 3 9479 1443| E: humanethics@latrobe.edu.au.

La Trobe University wishes you every continued success in your research.

Warm regards,

David Finlay
Chair, University Human Ethics Committee

Review by University Human Ethics Committee for Modification to Application: HEC16-137 mod 2

HE

Human Ethics
Thu 25/01/2018 16:01
To: Joanne Kemp
Cc: DENISE MARY JONES

LA TROBE UNIVERSITY

ETHICS, BIOSAFETY AND INTEGRITY – RESEARCH OFFICE

MEMORANDUM

To: **Dr Joanne Kemp, School of Allied Health, College of SHE**

From: **Human Ethics Officer, University Human Ethics Committee (UHEC)**
Reference: **HEC16-137 - Ethics application for modification to project - approved mod 2**
Title: **Risk factors for early hip osteoarthritis: A longitudinal cohort study**
Date: **25/01/2018** **Project End Date: 01/07/2019**

Thank you for submitting your modification request for ethics approval to the University Human Ethics Committee (UHEC) for the project referred to above. The UHEC has reviewed and approved the following modification/s which may commence now:

1. **Expanding data collection to two further sites:**
   - **Hobart (Surgeon – Mr Michael Pritchard)**
   - **Brisbane (Surgeon – Mr Gauguin Gamboa)**
2. **Extension until 01/07/2019**

Please note that your request has been reviewed by a sub-committee of the UHEC to facilitate a decision before the next Committee meeting. This decision will require ratification by the UHEC and it reserves the right to alter conditions of approval or withdraw approval at that time. However, you may commence prior to ratification and you will be notified if the approval status of your project changes.
The following standard conditions apply to your project:

- **Limit of Approval.** Approval is limited strictly to the research proposal as submitted in your application while taking into account any additional conditions advised by the UHEC.
- **Variation to Project.** Any subsequent variations or modifications you wish to make to your project must be formally notified to the UHEC for approval in advance of these modifications being introduced into the project. This can be done using the appropriate form: *Ethics - Application for Modification to Project* which is available on the Research Office website at http://www.latrobe.edu.au/researchers/research-office/ethics/human-ethics If the UHEC considers that the proposed changes are significant, you may be required to submit a new application form for approval of the revised project.
- **Adverse Events.** If any unforeseen or adverse events occur, including adverse effects on participants, during the course of the project which may affect the ethical acceptability of the project, the Chief Investigator must immediately notify the Senior Human Ethics Officer humanethics@latrobe.edu.au. Any complaints about the project received by the researchers must also be referred immediately to the Senior Human Ethics Officer.
- **Withdrawal of Project.** If you decide to discontinue your research before its planned completion, you must advise the UHEC and clarify the circumstances.
- **Monitoring.** All projects are subject to monitoring at any time by the UHEC.
- **Annual Progress Reports.** If your project continues for more than 12 months, you are required to submit an *Ethics - Progress/Final Report Form* annually, **on or just prior to 12 February**. The form is available on the Research Services website (see above address). Failure to submit a Progress Report will mean approval for this project will lapse.
- **Auditing**. An audit of the project may be conducted by members of the UHEC.
- **Final Report.** A Final Report (see above address) is required within six months of the completion of the project.

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

Plain Language Information Statement

LA TROBE SPORT AND EXERCISE MEDICINE RESEARCH CENTRE

PROJECT TITLE:	**Risk factors for early hip osteoarthritis: A longitudinal cohort study**
PRINCIPAL RESEARCHER:	**Dr Joanne Kemp (La Trobe University)**
OTHER RESEARCHERS:	**Professor Kay Crossley (La Trobe University)** **Dr Ilana Ackerman (Monash University)** **Denise Jones (La Trobe University)**

Background and purpose

This is an invitation for you to participate in a research study of people with hip pain, which involves patients undergoing hip arthroscopy for impingement and labral tears. Patients who consult an orthopaedic surgeon for hip pain to have hip arthroscopy surgery for hip impingement and/or labral tears, will be invited to take part in the study. Hip arthroscopy is a relatively new surgical procedure for patients with hip pain to reduce pain and improve function. This study is designed to determine the natural progression and recovery for hip arthroscopy, particularly with respect to reducing pain and improving function for people with hip pain and hip impingement and/or labral tears.

What do I need to do?

We are contacting you on behalf of your hip orthopaedic surgeon regarding a study we are working together on. If you are interested in participating, please read the information contained below. You will have the opportunity to ask questions, and you will be asked for your consent (via email) prior to proceeding. If you are NOT interested in participating, please let us know and you will not be contacted again.

The research team

Dr Joanne Kemp is a post-doctoral research fellow and clinical sports physiotherapist of 25 years' experience. She has extensive experience in research and clinical treatment of hip pain and pathology, and hip arthroscopy rehabilitation. Professor Kay Crossley is a physiotherapy professor and sports physiotherapist of >30 years' experience. She has extensive experience in studies of musculoskeletal injury. She has extensive experience with clinical studies and rehabilitation for musculoskeletal pain and osteoarthritis in the hip and knee. Associate Professor Ilana Ackerman is a musculoskeletal researcher and orthopaedic physiotherapist, with 20 years' clinical experience. She has successfully conducted a range of clinical and epidemiological studies involving younger and older people with hip and knee osteoarthritis. Denise Jones is a physiotherapist with 25 years

of experience. She has post-graduate qualifications in manual and sports physiotherapy and is currently completing her PhD.

What does the study involve?

If you agree to take part in the study, this will involve you in two elements of data collection:

1. The completion of on-line questionnaires.

You will be asked to complete some on-line questionnaires via an email link when you first join the study. These will take approximately 15 minutes to complete. The questionnaires ask about your hip pain and its impact on your ability to participate in daily and sporting activities. The same questionnaires will be repeated at 6, 12 and 24 months following the surgery along with a short (approximately 2 minute) questionnaire at 3, 6 and 12 months following your operation. We will also access your medical records to obtain information about your scans taken of your hip prior to surgery, and details of your surgical procedure.

2. Activity data using the Fitbit Flex.

To undertake this part of the study you will be provided with a Fitbit Flex. This will be sent out to you in the post. ***You can keep the Fitbit Flex device at the conclusion of the study.***

You will need a suitable device **(smartphone, tablet or computer) on which to set up the Fitbit app.** Not all smart phones are compatible. The list can be checked at the following link https://www.fitbit.com/au/devices. If you are unsure, please contact us and we can check this information. We can offer telephone and on-line support if you experience any difficulties setting up the device.

Once the device is set up you will have access to your own Fitbit interface (called a dashboard), the same as any other user. The research team will also access your data via this dashboard. Data collection will take place at specified intervals (at initial set up; 6 weeks post op; 3 months post op; 6 months post op and 1 year). Data collection at initial set up will be for a duration of 7 days. Data collection periods following this will be for a period of 2 weeks. You will be contacted via text and/or email one week prior to each intended data collection period to ensure that there are no barriers to wearing the Fitbit for the intended 2 weeks and address any problems that may have arisen. Data will exported for the specified dates of the data collection period only. This will be a daily total of calories, steps, distance and physical activity categorised as ‘sedentary’, ‘lightly active’, fairly active’ and ‘very active’. The data is exported from the website as a spread sheet (CSV format).

Once the Fitbit is linked to your computer/phone, the information from the Fitbit will be automatically synched to your mobile device via blue tooth and can also be synced to a computer via a USB dongle.

Your Fitbit is linked to an email account. As the research team have no requirement to access the email account, your personal email account can be used during the set up of the device. Linking the device to your own email allows you to receive information from Fitbit on your progress and notifications such as 'low battery'. The research team will need to maintain your email address to access the Fitbit website, however we will have no password details and will be unable to access your email account. If you do not have an email account, or would prefer a separate account for this device, this can be established at the time the device is set up.

A secondary aim is to assess the feasibility of using Fitbits in a long term study such as this. Consequently we will also be asking about your experience of using the tracker within this context.

In addition, you may also be asked for additional consent to be contacted five years and ten years after surgery for further follow-up.

Additional study information.

In order to gain a more in-depth understanding of participants' experiences in returning to physical activity following surgery, we are also offering the opportunity to undertake telephone interviews as outlined below.

You are free to be involved in either or both parts of the study.

Telephone interviews about your outcomes and experiences 6 months following hip arthroscopy.

If you are interested in undertaking this element of the study you will be contacted by phone or email (stated preference) approximately 6 months following the date of your surgery to arrange a convenient time for the telephone interview to take place. Each interview is expected to take 15 – 30 min to complete and will allow us to investigate the experiences you have had in relation to your hip problem and the impact it has had on your life. The interviews will be undertaken by a member of the research team who is not involved in your care. Any information disclosed will remain confidential and will not affect your surgical or physiotherapy care.

Each telephone interview will be recorded and transcribed.

If your relating your experiences causes you undue distress please contact your GP or Lifeline (13 11 14).

If you have concerns relating to the conduct of any health service provider, please contact:

Victoria - Health Services Commissioner (1300 582 113; E-Mail: hsc@dhhs.vic.gov.au).

Tasmania – Health Complaints Commissioner Tasmania (1800 001 170; email healthcomplaints.tas.gov.au).

Brisbane – Office of the health ombudsman Queensland (133 133 646; email info@oho.qld.gov.au).

Potential advantages, disadvantages and serious adverse events

The main advantage is potential for future patients with hip pain who are in your position and are considering undergoing hip arthroscopy surgery. We will have a better understanding of the condition, the risk factors for reducing pain and improving function.

The main disadvantage for participation is your time commitment. Completing the questionnaires is estimated to take 15 minutes You will be asked to do this on 3 occasions over a 2 year period. During activity data collection periods it will be necessary to charge the Fitbit device (approximately every four days) and sync the device with the app at least every five days. Serious adverse events are very unlikely, A few users have reported an allergic reaction to the strap of the Fitbit. Should you get any irritation of your skin, please stop using the device immediately.

The Fitbit Flex is only splash proof and should not be worn for activities such as swimming, bathing or showering.

It is important that you are able to wear the device every day during the data collection periods, however certain sports codes and work activities may ban the wearing of devices around the wrist. Please do not wear the Fitbit if any of these restrictions apply.

What will happen to your personal information?

The samples and data that are registered about you will only be used in accordance with the purpose of the study as described above. Your data will be re-identifiable. This means that the information is processed without your name, personal identification number or other directly recognisable type of information. Instead a code number links you to your data. This code list is stored at the clinic/hospital only, and only the authorised study staff will have access to this list. Confidentiality of your personal information is a priority, subject to legal limitations. Data from any element of this and any follow-up studies will be destroyed 5 years after the final report is published. It will not be possible to identify you in the results of the study when these are published.

Plain Language Information Statement

Voluntary participation

Participation in the study is voluntary. Choosing to participate or not has no impact on the treatment provided by your surgeon. You can withdraw your consent to participate in the study at any time and without stating any particular reason. If you agree to undertake any additional element of the study, you are free to withdraw from any/ all of these elements individually without effecting your participation in the core study. You will be asked to sign a consent that confirms your involvement in the project is voluntary and that you are free to withdraw at any time, or withdraw any unprocessed data previously supplied. This will not have any consequences for your further treatment.

Additional Information

This study has received funding from the Physiotherapy Research Foundation (Australian Physiotherapy Association). If requested, participants will be provided with a copy of the results of the study at its conclusion via email. The results of this study will be presented at national and international sports medicine and rheumatology conferences and will be published in international peer-reviewed journals.

Can I change my mind?

If you change your mind, no further data will be collected, and any data that has not been analysed prior will be destroyed. If your data has already been analysed then it is not possible to remove that data.

If you have any questions, or you would like further information regarding the project titled ***Risk factors for early hip osteoarthritis: A longitudinal cohort study***, please contact the Principal Researcher, ***(Dr Joanne Kemp)***

PH: 03 94791428
EMAIL: j.kemp@latrobe.edu.au

If you have any complaints or concerns about your participation in the study that the researcher has not been able to answer to your satisfaction, you may contact the Senior Human Ethics Officer, Ethics and Integrity, Research Office, La Trobe University, Victoria, 3086 (P: 03 9479 1443, E: humanethics@latrobe.edu.au) . Please quote the application reference number HEC 16-137.

Consent Form

PROJECT TITLE:	**Risk factors for early hip osteoarthritis: A longitudinal cohort study**
RESEARCHERS:	**Dr Joanne Kemp, Professor Kay Crossley, Dr Ilana Ackerman, Denise Jones**

Consent – Please complete the following information:

I, ... of . . . . . .
. . . . . .
hereby consent to participate as a subject in the above research.
In addition I consent to take part in:

	YES	NO	Initial
▪ The collection of activity data using Fitbit Flex™	☐	☐	☐
▪ Telephone interviews about your outcomes and experiences 6 months following surgery for FAI.	☐	☐	☐
I agree to the audio recording of telephone interviews.	☐	☐	☐

The research program in which I am being asked to participate has been explained fully to me, verbally and in writing, and any matters on which I have sought information have been answered to my satisfaction.

I understand that: all information I provide (including questionnaires) will be treated with the strictest confidence and data will be stored separately from any listing that includes my name and address.

- aggregated results will be used for research purposes and may be reported in scientific and academic journals
- ***I am free to withdraw my consent at any time during the study in which event my participation in the research study will immediately cease and any information obtained from it will not be used.***
- ***once information has been aggregated it is unable to be identified, and from this point it is not possible to withdraw consent to participate***

SIGNATURE: . . . . . **DATE**: . . . . . .

APPENDIX 7: EXAMPLE OF ADDITIONAL INFORMATION FOR USE OF FITBIT™

Fitbit Flex™

Your password is: ……..

Your email address is: …… This email is also your **username**, which you will use to log on to the website or app.

How to use your Fitbit Flex™

1. What do I get in the box?

You should have:

*2 wrist bands (pick the one that fits you best)

*One charging dock

*One tracker – this is the business bit of the kit.

*One wireless sync dongle – you should keep this plugged into the USB port of your computer to enable the Fitbit Flex™ to sync.

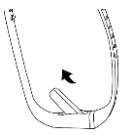
2. Setting up your Fitbit Flex™:

Prior to setting up the device, it will require charging.
To set up the device you will need to download the Fitbit app onto your preferred device. The app will ask you if you wish to 'join' or 'log in'. You join using the user name and password provided above. The app will then take you through the set up process. For best results from the device you need to include your height, weight and age. Please set the hand dominance to **'non-dominant'** and wear the device on your **non-dominant** wrist.
Fitbit will intermittently request updates to be completed on the device – please do these as it helps the device to function more efficiently.
If you need further information try **'http://help.fitbit.com'** - choose the 'flex' option. Answers to questions can be found fairly easily using the search facility.

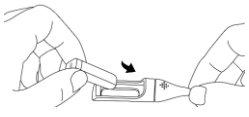
Charging:

The battery should last for 5 to 7 days. Please charge it every 5 days and do so during the night so that we lose a minimal amount of activity data.

Remove the Fitbit Flex™ from the wrist band

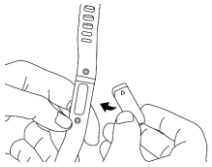


Place the Fitbit Flex™ in the charger, aligning the 'gold dots'



We recommend you to only use a USB port of a computer to charge it, not an outlet. You will know it is fully charged when all 5 lights come on.

Replace the Fitbit Flex™ in the wristband, arrow pointing toward the display section of the band.



Using your Fitbit Flex™:

You can set up your Fitbit Flex™ using your Smartphone, tablet or desktop. To capture all the data, you will need to ensure your Fitbit is synced at least every 5 days. This can be done via blue tooth on you smartphone or via the dongle using a computer.

During data collection, the Fitbit should be worn during waking hours for all activities other than water-based activities (such as swimming and bathing) and contact sports. The Fitbit can be removed when sleeping.

There are some activities that are less accurately logged by the Fitbit Flex™, such as cycling or rowing. Activities can be logged separately if you would like to do so via the 'dashboard' with 'add activity'.

Privacy:

Your privacy can be checked via 'settings'. We recommend that your privacy settings should be set so that only you can see your information.

What data can we see and how will it be collected?

The data collected by the research team will be gathered by exporting information from the Fitbit dashboard at specific intervals. These will be at set-up, 6, 12, 24 and 52 weeks post operatively for a period of two weeks. We will contact you the week before to check that you are having no problems with the device and remind you that the data collection period is pending.
It is important that you maintain the log in and password provided on the first page in order to allow the research team to collect the data.

Problems?

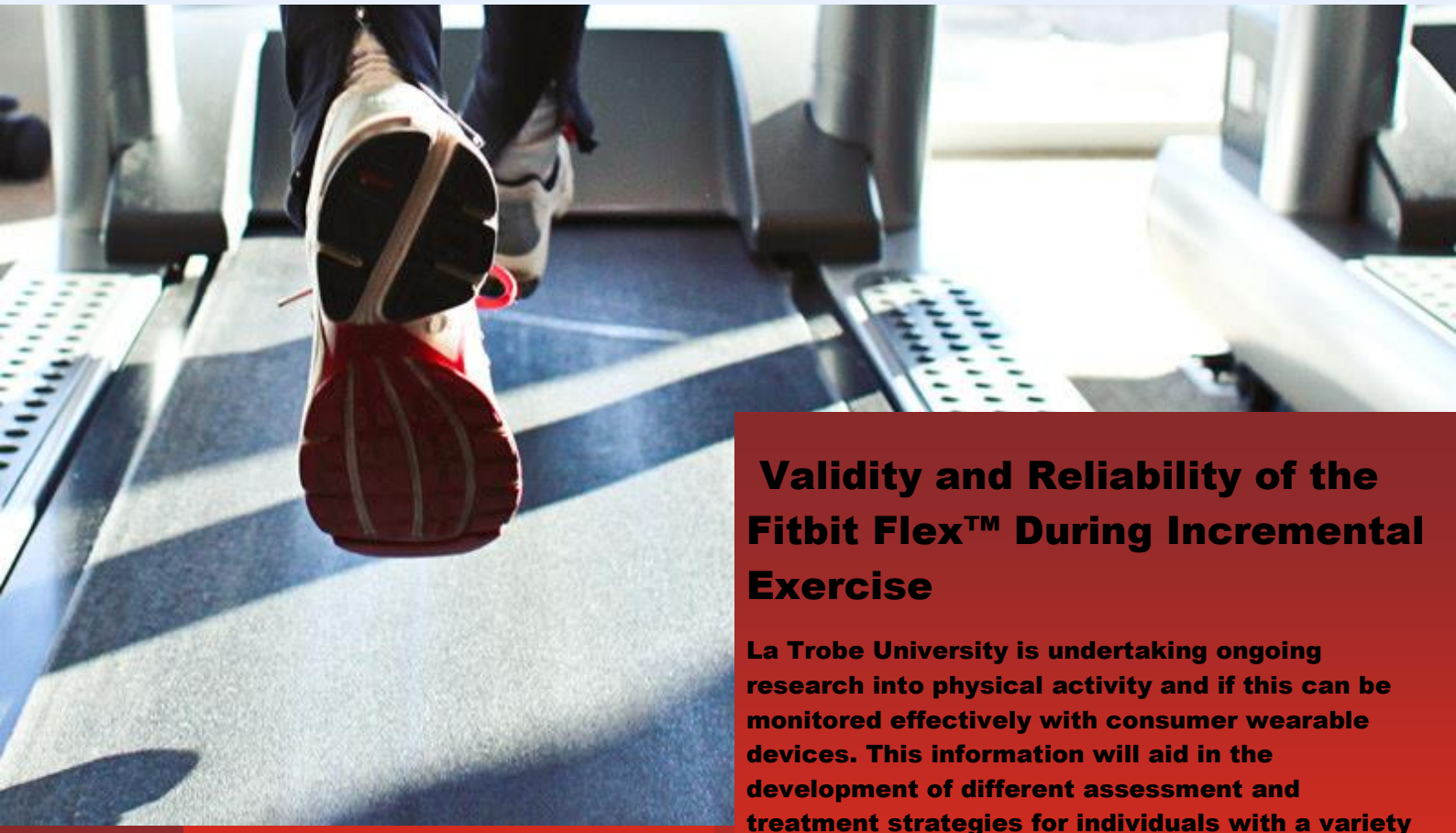
If any problems should arise regarding your use of the Fitbit Flex™, please don't hesitate to contact me via email (jones.d@students.latrobe.edu.au).
Glitches do occur with the devices and we are happy to hear from you if it is giving you any problems.

Thank you for your time and support.

APPENDIX 8: EXAMPLES OF RECRUITMENT ADVERTISING

LA TROBE UNIVERSITY

LA TROBE SPORT & EXERCISE MEDICINE RESEARCH CENTRE



Validity and Reliability of the Fitbit Flex™ During Incremental Exercise

La Trobe University is undertaking ongoing research into physical activity and if this can be monitored effectively with consumer wearable devices. This information will aid in the development of different assessment and treatment strategies for individuals with a variety conditions.

Recruiting now!

Are you aged between 18 -50 years old?

Do you love to run? ☺

Have you ever wondered how accurate activity monitors are?

Are you interested in participating in a research study to help us find out?

For further information please contact:

Dr Ben Dascombe

B.Dascombe@latrobe.edu.au
03 94795776.

Denise jones

Jones.d@students.latrobe.edu.au

LASEM Research Centre. HEC16-082
Chief Investigator: Kay Crossley (K.Crossley@LaTrobe.edu.au; 03 94793902)

LA TROBE UNIVERSITY

LA TROBE SPORT & EXERCISE MEDICINE RESEARCH CENTRE

Recruiting now!

Are you aged between 18 - 50 years old?

Have you ever wondered how accurate activity monitors are?

Are you interested in participating in a research study to help us find out?

Validity And Reliability Of Wearable Technology In A Free-living Environment

La Trobe University is undertaking ongoing research into physical activity and if this can be monitored effectively with consumer wearable devices. This information will aid in the development of different assessment and treatment strategies for individuals with a variety conditions.

For further information please contact:

Denise jones

Jones.d@students.latrobe.edu.au

Harvi Hart

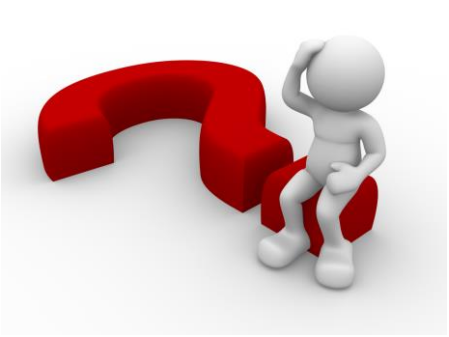
h.hart@latrobe.edu.au

LASEM Research Centre. HEC16-082
Chief Investigator: Kay Crossley (K.Crossley@LaTrobe.edu.au; 03 94793902)

LA TROBE UNIVERSITY

HOW PHYSICALLY ACTIVE ARE YOU?

Could you help us answer this question?



We are aiming to monitor the progression of physically activity following hip arthroscopy.

The Fitbit Flex™ is a small wrist worn device that monitors physical activity. Information from the device is accessed via an app that can be installed on your phone, tablet or computer.

YOU ARE POTENTIALLY ELIGIBLE TO TAKE PART IF:

- You are having a hip arthroscopy or have had one in the last 12 months.
- You are aged between 18 and 50.
- You have access to a smart phone, tablet or computer
- You are able to wear a Fitbit during your average day (i.e. no work health and safety restrictions in relation to wrist worn devices).

LASEM RESEARCH CENTRE. HEC16-137
CHIEF INVESTIGATOR: DR JOANNE KEMP
(j.kemp@latrobe.edu.au; 03 9479 2169)

Free Fitbit™

MORE INFORMATION

For additional information please contact us:

Denise Jones

LASEM RESEARCH CENTRE

E jones.d@students.latrobe.edu.au

www.latrobe.edu.au

APPENDIX 9: STUDY 4, APPENDICES 9A & 9B

9a. Non-participants- demographic data and comparison with participants.

	Group 1	Group 2	Group 3	Group 4
Non-participants (n)	Healthy Controls (n=4)	FORCe (n=43)	PhysioFIRST (n=27)	HARP (n=75)
Non-participants (% of cohort)	10	72	41	62
Sex (%male:%female)	50:50	91:9	48:52	51:49
Age mean±SD [range] years	32±11 [26 to 48]	25±4 [18 to 35]	35±8 [20 to 47]	35±9 [21 to 50]
BMI mean±SD [range] kg/m²	21±20 [20 to 29]	25±3 [19 to 33]	25±5 [16 to 36]	Unknown
Statistical significance between participants and non-participant groups				
Sex	Not calculated due to sample size	p=0.645	p=0.320	p=0.141
Age		p=0.196	p=0.292	p=0.346
BMI		p=0.731	p=0.360	No data
iHOT-33 SR		p=0.120	p=0.486	No data

FORCe=Femoroacetabular impingement and hip OsteoaRthritis Cohort; PhysioFIRST=The physiotherapy for Femoroacetabular Impingement Rehabilitation Study; HARP=Hip ARthroscopy Prospective Study; SD=standard deviation; BMI=Body mass index (kg/m²); iHOT-33 SR=International Hip Outcome Tool –Sports and Recreational activities subscale

9b - Determining suitability of regression models.

	Independent variables/covariates (included)	df	F	p	Adjusted R^2
Model 1	Group	3	0.474	0.701	-0.014
Model 2	Group	3	1.382	0.252	0.044
	Age	1	4.040	*0.047	
	Group & age interaction	3	1.451	0.232	
Model 3	Group	3	0.645	0.588	0.032
	Age	1	6.326	*0.013	
Model 4	Group	3	1.392	0.249	0.111
	Age	1	9.141	*0.003	
	Sex	1	7.435	*0.007	
	Group & sex interaction	3	1.308	0.276	
†Model 5	Group	3	0.644	0.588	0.103
	Age	1	9.071	*0.003	
	Sex	1	9.809	*0.002	

*significant (p<0.05); †chosen as the most suitable final model

APPENDIX 10: STUDY 5 – APPENDED DOCUMENTS A AND B

Consolidated criteria for reporting qualitative studies (COREQ): 32-item checklist

Developed from:
Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*. 2007. Volume 19, Number 6: pp. 349 – 357

No. Item	Guide questions/description	Reported on Page #
Domain 1: Research team and reflexivity		
Personal Characteristics		
1. Inter viewer/facilitator	Which author/s conducted the inter view or focus group?	
2. Credentials	What were the researcher's credentials? E.g. PhD, MD	
3. Occupation	What was their occupation at the time of the study?	
4. Gender	Was the researcher male or female?	
5. Experience and training	What experience or training did the researcher have?	
Relationship with participants		
6. Relationship established	Was a relationship established prior to study commencement?	.
7. Participant knowledge of the interviewer	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	
8. Interviewer characteristics	What characteristics were reported about the inter viewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	

Domain 2: study design		
Theoretical framework		
9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	
Participant selection		
10. Sampling	How were participants selected? e.g. purposive, convenience, consecutive, snowball	
11. Method of approach	How were participants approached? e.g. face-to-face, telephone, mail, email	
12. Sample size	How many participants were in the study?	
13. Non-participation	How many people refused to participate or dropped out? Reasons?	
Setting		
14. Setting of data collection	Where was the data collected? e.g. home, clinic, workplace	.
15. Presence of non-participants	Was anyone else present besides the participants and researchers?	
16. Description of sample	What are the important characteristics of the sample? e.g. demographic data, date	
Data collection		
17. Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	
18. Repeat interviews	Were repeat interviews carried out? If yes, how many?	
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?	
20. Field notes	Were field notes made during and/or after the inter view or focus group?	
21. Duration	What was the duration of the inter views or focus group?	
22. Data saturation	Was data saturation discussed?	
23. Transcripts returned	Were transcripts returned to participants	

	for comment and/or correction?	
Domain 3: analysis and findings		
Data analysis		
24. Number of data coders	How many data coders coded the data?	
25. Description of the coding tree	Did authors provide a description of the coding tree?	
26. Derivation of themes	Were themes identified in advance or derived from the data?	
27. Software	What software, if applicable, was used to manage the data?	
28. Participant checking	Did participants provide feedback on the findings?	
Reporting		
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	
30. Data and findings consistent	Was there consistency between the data presented and the findings?	
31. Clarity of major themes	Were major themes clearly presented in the findings?	
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	

Appendix B. Interview guide

Interview guide
How would you describe your involvement with physical activity or sport? *(level of activity, type of activity, social importance, motivations, impact of hip condition)*
How important did you feel it was to return to your pre-injury level of activity? *(relate to other life experiences)*
What were your hip problems like before surgery? *(duration, onset, impact on physical activity)*
Can you tell me about the decision to have surgery? *(motivations, options, expected outcomes).*
Has the surgical process been as you expected? *(preparation, information, experiences with healthcare professionals)*
Can you tell me about your rehabilitation? *(progress, content, deciding to progress)*
How have you felt since your surgery? *(physically, emotionally)*
What impact are your hip symptoms having on your life currently? *(physical limitations, social limitations, work limitations, mental wellbeing)*
Can you describe how confident you feel about your hip?
Can you tell me about any fears you may have in relation to your hip? *(re-injury, future symptoms, changing physical activity goals)*

REFERENCES

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