BMJ Open

Protocol: Comparing exercise and patient education with usual care in the treatment of hip dysplasia: a randomised controlled trial with six-month follow-up (MovetheHip trial)

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-064242
Article Type:	Protocol
Date Submitted by the Author:	28-Apr-2022
Complete List of Authors:	Jacobsen, Julie; Research Unit for General Practice; VIA University College, Research Centre for Health and Welfare Technology, Programme for Rehabilitation Thorborg, Kristian; Copenhagen University Hospital, Amager-Hvidovre, Sports Orthopaedic Research Center-Copenhagen (SORC-C), Department of Orthopaedic Surgery; Copenhagen University Hospital, Amager-Hvidovre, Physical Medicine and Rehabilitation Research-Copenhagen (PMR-C), Department of Physical and Occupational Therapy Nielsen, Rasmus; Aarhus University, Department of Public Health; Research Unit for General Practice Jakobsen, SS; Aarhus University Hospital, Department of Orthopaedic Surgery; Aarhus University, Department of Clinical Medicine Foldager, C; Aarhus University Hospital, Department of Orthopaedic Surgery Sørensen, Dorthe; VIA University College, Research Centre for Health and Welfare Technology, Programme for Rehabilitation Oestergaard, Lisa; Defactum, Central Denmark Region; Aarhus University Hospital, Department of Occupational Therapy and Physiotherapy van Tulder, Maurits; Vrije Universiteit Amsterdam, Department of Human Movement Sciences, Faculty of Behavioural and Movement Sciences Mechlenburg, Inger; Aarhus University Hospital, Department of Orthopaedic Surgery; Aarhus University, Department of Clinical Medicine
Keywords:	Hip < ORTHOPAEDIC & TRAUMA SURGERY, Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY, SPORTS MEDICINE, REHABILITATION MEDICINE

PROTOCOL: COMPARING EXERCISE AND PATIENT EDUCATION WITH USUAL CARE IN THE TREATMENT OF HIP DYSPLASIA: A RANDOMISED CONTROLLED TRIAL WITH SIX-MONTH FOLLOW-UP (MOVETHEHIP TRIAL)

Authors

Julie Sandell Jacobsen[1,2], Kristian Thorborg[3,4], Rasmus Oestergaard Nielsen[2,5], Stig Storgaard Jakobsen[6,7], Casper Foldager[6], Dorthe Sørensen[1], Lisa Gregersen Oestergaard[5,8,9], Maurits W van Tulder[9,10], Inger Mechlenburg[5,6,7]

Affiliations

[1]Research Centre for Health and Welfare Technology, Programme for Rehabilitation, VIA University College, Aarhus, Denmark

[2]Research Unit for General Practice, Aarhus, Denmark

[3]Sports Orthopaedic Research Center-Copenhagen (SORC-C), Department of Orthopaedic Surgery, Copenhagen University Hospital, Amager-Hvidovre, Hvidovre, Denmark

[4]Physical Medicine and Rehabilitation Research-Copenhagen (PMR-C), Department of Physical and Occupational Therapy, Copenhagen University Hospital, Amager-Hvidovre, Hvidovre, Denmark

[5]Department of Public Health, Aarhus University, Aarhus, Denmark

[6]Department of Orthopaedic Surgery, Aarhus University Hospital, Aarhus, Denmark

[7]Department of Clinical Medicine, Aarhus University, Aarhus, Denmark

[8]DEFACTUM, Central Denmark Region, Aarhus, Denmark

[9]Department of Occupational Therapy and Physiotherapy, Aarhus University Hospital, Aarhus, Denmark

[10]Department of Human Movement Sciences, Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Netherlands

Corresponding author

Julie Sandell Jacobsen, Research Centre for Health and Welfare Technology, Programme for Rehabilitation, VIA University College, Hedeager 2, 8200 Aarhus N, Denmark. E-mail: jsaj@via.dk

Word count: 3,894 words

ABSTRACT

Introduction

Surgery is not a viable treatment for all patients with hip dysplasia. Currently, usual care for these patients is limited to a consultation on self-management. We have shown that an exercise and patient education intervention is a feasible and acceptable intervention for patients not receiving surgery. Therefore, we aim to investigate if patients with hip dysplasia randomised to exercise and patient education have a different mean change in self-reported pain compared with those randomised to usual care over six months. Furthermore, we aim to evaluate the cost-effectiveness and the processes of exercise and patient education.

Methods and analysis

In a randomised controlled trial, 200 patients will be randomised to either exercise and patient education or usual care at a 1:1 ratio through permuted block randomisation. The intervention group will receive exercise instructions and patient education over six months. The usual care group will receive one consultation on self-management of hip symptoms. The primary outcome is the self-reported mean change in the pain subscale of the Copenhagen Hip and Groin Outcome Score (HAGOS). Secondary outcomes include mean changes in the other HAGOS subscales, in the Short Version of the International Hip Outcome Tool (iHOT-12), in performance, balance and maximal hip muscle strength. Between-group comparison from baseline to six-month follow-up will be made with intention-to-treat analyses with a mixed-effects model. Cost-effectiveness will be evaluated by relating quality-adjusted life years and differences in HAGOS pain to differences in costs over 12 months. The functioning of the intervention will be evaluated as implementation, mechanisms of change and contextual factors.

Ethics and dissemination

The study protocol was approved by the Committee on Health Research Ethics in the Central Denmark Region and registered at ClinicalTrials. Positive, negative and inconclusive findings will be disseminated through international peer-reviewed scientific journals and international conferences.

Trial registration number: NCT04795843

Keywords

Hip < ORTHOPAEDIC & TRAUMA SURGERY, Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY, SPORTS MEDICINE, REHABILITATION MEDICINE

STRENGTHS AND LIMITATIONS OF THIS TRIAL

- This trial is the first to compare exercise and patient education with usual care in patients with hip dysplasia.
- A feasibility study including qualitative and quantitative data preceded this trial.
- The investigation includes a clinical evaluation, a health-economic evaluation and a process evaluation.
- The intervention is designed to fit into the patients' everyday life with a potential for large-scale use.
- A limitation of this trial is the inability to blind participants and intervention providers.

INTRODUCTION

Hip dysplasia is the medical term for a hip joint with a reduced acetabular weight-bearing area.[1] The prevalence proportion of radiographic findings is 3-20% in the general population[2,3] and 19-32% in adults with hip pain.[2,4] Hip dysplasia can present in infancy or in young adulthood,[5] and hip dysplasia is associated with early osteoarthritis.[6–9] The joint disease affects mainly young to middle-aged women,[10] and many have a familial predisposition.[11] The most common symptom is groin pain, which is associated with high day-to-day variation in pain intensity,[10,12,13] and this unpredictability is perceived as the most challenging aspect to cope with.[14]

Young and middle-aged adults with hip dysplasia are often exposed to daily physical demands due to occupational and family-related responsibilities.[15] Physical limitations imposed by hip problems challenge their perception of being physically active and independent, which may affect their personal identity, confidence and self-esteem.[10,14,16–18] This bio-psycho-social impact of hip dysplasia call for effective and individualised treatment options.[14] Periacetabular osteotomy (PAO) is a well-accepted surgical treatment for patients with pain.[19] Yet, a PAO is not always a viable treatment option for all patients. Patients with a BMI above 25, age above 45 years or hip osteoarthritis may not be offered a PAO since worse outcomes are associated with these characteristics.[20–22] Besides, a subgroup of the patients offered a PAO are not willing to undergo surgery. Currently, usual care for these patients is limited to a single consultation on self-management of hip symptoms.

We recently completed a feasibility study on an exercise and patient education intervention for patients not receiving a PAO. The results showed a high willingness to be recruited and acceptable retention. We found clinical relevant improvements in pain, physical function and maximum hip muscle strength with a high intervention acceptance.[15] The feasibility study contributed to refinement of the intervention, the data collection and the recruitment procedures. Thus, it seems feasible to conduct a full-scale randomised controlled trial (RCT) to investigate the effectiveness of an exercise and patient education on pain, physical functioning and maximum hip muscle strength.

The primary aim of this effectiveness trial is to investigate if patients with hip dysplasia who are randomised to exercise and patient education have a different mean change in self-reported pain measured by the Copenhagen

Hip and Groin Outcome Score (HAGOS) compared with those randomised to usual care over a six-month follow-up period. Secondary aims are to compare mean changes between the two groups on the other HAGOS subscales over a six-month follow-up period. Similar comparisons will be made on self-reported mean changes in the Short Version of the International Hip Outcome Tool (iHOT-12) and mean changes in performance, balance and maximum hip muscle strength. We hypothesise that patients randomised to exercise and patient education will have a between-group mean change score on the HAGOS pain that is at least 10 points higher than those randomised to usual care over a six-month follow-up period.

In a health-economic evaluation, we will investigate the cost-utility and cost-effectiveness of exercise and patient education compared with usual care over 12 months. Furthermore, in a process evaluation, we will explore the functioning of the intervention by evaluating the implementation, mechanisms of change and the contribution of contextual factors over six months.

METHODS AND ANALYSIS

Trial design

This study is a parallel-group superiority RCT following the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) guidelines.[23] The treatments are described according to the Consensus on Exercise Reporting Template (CERT) guidelines.[24] Permuted block randomisation will be used with a 1:1 ratio with the primary end-points after six months. The first participant was enrolled in April 2021, and enrolment is expected to be completed by December 2025.

Study setting

We will recruit participants from the Department of Orthopaedic Surgery at Aarhus University Hospital in Denmark. Orthopaedic surgeons, specialised in hip dysplasia, will apply eligibility criteria and will provide oral and written information to patients with hip dysplasia as part of an initial screening. Following an initial screening, the principal investigator (PI) will contact patients willing to participate by phone and will verify the eligibility criteria. The PI will provide detailed oral information about the trial objective, clinical implication, procedures, funding and possible adverse events. Following this, the PI will obtain informed consent by sending a personal electronic letter to the

individual patient's eBoks, which is a national secure electronic mailbox for encrypted digital communication between citizens, private companies and public authorities in Denmark.

Eligibility criteria

Inclusion criteria: (1) 18-50 years of age; (2) radiographically verified hip dysplasia (Wiberg's center edge (CE) angle 10-25 degrees[25] and an acetabular index (AI) angle >10 degrees[26]); (3) hip and/or groin pain (primary pain complain) for at least three months; (4) eligible but unwilling to undergo PAO or not eligible for PAO (negative impingement test, BMI >25, Tönnis hip osteoarthritis score >1, age >45 years or reduced hip range of motion (<95° flexion or <30° abduction)). Exclusion criteria: (1) HAGOS pain score >80 points; (2) any major planned surgery (arthroplasty or discectomy surgery); (3) BMI >35; (4) acetabular retroversion defined by crossover sign and posterior wall sign; (5) Calvé Legg Perthes or epiphysiolysis; (6) previous pelvic/hip surgery in index limb; (7) previous pelvic/hip surgery within two years in contralateral limb; (8) previous surgery due to herniated disc or spondyloses; (9) previous arthroplasty in the lower limb; (10) previous trauma, neurological, medical or rheumatological conditions affecting the hip function; (11) inadequacy in written and spoken Danish, pregnancy, mental illness or other conditions affecting the ability to follow mandatory stages for participation.

Randomisation

Following enrolment and a baseline assessment, participants will be randomised to exercise and patient education or usual care at a 1:1 ratio through permuted block randomisation with randomly varying block sizes of 4 to 6 (Figure 1). An independent data manager will set up a computer-generated list of random numbers in the Research Electronic Data Capture (REDCap) randomisation system before the inclusion of participants. The group allocation will be concealed since a research assistant not involved in the outcome assessment will perform the randomisation without being able to foresee group assignment. The research assistant will inform the PI about group allocation, and the PI will assign participants to one of the two groups. The participants will start treatment closely thereafter.

Blinding

Neither the participants nor the intervention providers will be blinded to the treatment allocation. Outcome assessors will be blinded to treatment allocation, and the participants will be instructed not to disclose their

allocation when outcomes are assessed. The primary outcome is self-reported. Therefore, we will blind participants to previous testing scores and the trial hypothesis. A data analyst blinded to the treatment allocation will perform all pre-defined analyses on coded data. Only the PI will have the key access to the electronically stored data with information about the treatment allocation.

Patient characteristics

The following will be registered at baseline: sex, age, height, weight, duration of hip symptoms, unilateral or bilateral hip dysplasia, educational level, employment status, cohabiting status, co-morbidities, previous surgery, level of physical activity and exercise, intra-articular pain using the Flexion-adduction-Internal-rotation (FADIR) test, centre-edge (CE) angle [25], acetabular index (AI) angle [26] and osteoarthritis grade evaluated with the Tönnis osteoarthritis classification [26]. A hip surgeon (SSJ) will measure the radiological characteristics using standardised standing anteroposterior radiographs. Weight, physical activity level and intra-articular pain will additionally be recorded at six-month follow-up.

Exercise and patient education (intervention)

The intervention was designed to reduce pain,[10,27] reduce physical limitations[16,28,29] and help patients cope with their pain and limitations in their everyday life.[14] In addition, it was designed as a flexible intervention requiring little time in order to motivate intervention adherence despite daily occupational and family-related responsibilities.

The intervention will follow a previously described protocol[15] and will be running over a period of six months (Table 1). The participants will be offered eight individual supervised training sessions. In these sessions, participants will be instructed in four exercises. Each of these exercises can be completed at three levels of difficulty, and all participants will start at the lowest level. The participants will be instructed to perform exercises on a perceived exertion level of 5-7 based on the Borg CR10 scale, i.e. somewhat hard (level 5), hard (level 6) or very hard (level 7),[30] and to perform a minimum of three training sessions at home each week. Additionally, participants will receive oral patient education about the mechanisms of pain in hip dysplasia,[27,31] the importance of regular physical activity and exercise,[32] the consequences of inactivity, the importance of exercise adherence, the advice to lose weight if relevant and that muscle soreness is to be expected.[33] The intervention

providers will use written treatment and exercise manuals, and the participants will be provided with paper-based exercise instructions.[15]

Table 1 Treatment delivery according to the Consensus on Exercise Reporting Template (CERT) for both groups

Topic	Item	Exercise and patient education intervention	Usual care
WHAT	1	The intervention does not require any equipment.	Usual care does not require any equipment.
WHO	2	Physical therapy students deliver the intervention under supervision by an expert team of physical therapists (UGB, KT & JSJ). Physical therapy students receive an hour of supervision per patient and four meetings with the expert team during the trial period. More details on this are provided in the supplemental material in Jacobsen et al.[15]	An experienced physical therapist delivers usual care (JSJ).
HOW	3	Exercise is provided one-to-one and delivered face-to-face.	Usual care is provided one-to-one and delivered face-to-face or by phone with video call as an option (optional to participants).
	4	Eight supervised training sessions are scheduled, including exercise instruction, correction of exercise performance, regression or progression of exercises and patient education. Sessions are scheduled as two sessions each month in the first two months and as one session each month in the last four months.	After one oral consultation, usual care is unsupervised.
	5	Adherence is documented by weekly logbook recordings and by completing the EARS at three- and six-month follow-up.	At six-month follow-up, adherence is registered by completing a standardised form on whether specific hip exercises were performed in the last six months and, if relevant, how frequent.
	6	Improvements in difficulty level of exercises, repetitions, pain or function are identified at the supervised training sessions to motivate participants to adhere to the intervention. Moreover, the rationale of exercising and the importance of regular and consistent training are given as part of the patient education.	Participants can call the usual care provider at any time for support to adhere to usual care. Moreover, rationale of physical activity, exercise and weight reduction (if relevant) will be delivered.
	7a	Participants are instructed in four exercises. Each of these exercises can be completed at three levels of difficulty (levels A, B, C; A being the highest level), and all participants start at level C. *First four weeks*: increase the number of repetitions up to 20 if the Borg CR10 scale is below three. *After four weeks*: progress to higher difficulty level of exercises and/or increase repetitions up to 20 if the Borg CR10 scale is below five. To progress to higher difficulty levels, the following criteria are mandatory: (1) an exercise is performed correct, (2) an exercise must be acceptable to participants with regard to pain and/or discomfort, (3) a minimum of 10 repetitions in three sets on the lower difficulty level can be completed.	N/A
	7b	One set on the lower (usual) difficulty level is done. If 1-3 are fulfilled, a higher level is probed. To exercise on the higher level, criteria 1-2 must be fulfilled, and the participant must be able to complete a minimum of five repetitions in sets of three on the higher difficulty level. Regression or progression is done at the supervised training sessions. At home, regression to lower difficulty level or fewer sets or repetitions are done if unacceptable pain or discomfort is experienced.	N/A
	8	Four exercises, a supine plank exercise, a side-lying plank exercise, a squat exercise and a one-leg stability exercise.[15]	One oral consultation on self-management of hip symptoms and advice on exercising and staying physically active. If relevant, advise to lose weight.

	9	Perform the four exercises at three weekly home-based training sessions	Perform regular physical activity and exercise and, if relevant, lose weight.
	10	Patient education: explain what hip dysplasia is, the rationale and importance of being physically active and exercising on a regular basis, education on tissue tolerance and pain mechanisms in hip dysplasia, knowledge about gains of specific exercis regimens and knowledge of the relation between overweight and pain.	Patient education: explain what hip dysplasia is, the rationale and importance of being physically active and exercising on a regular basis, education on tissue tolerance and pain mechanisms in hip dysplasia, gains of physically active lifestyle, and knowledge of the relation between overweight and pain.
	11	SAE and AE are registered at three- and six-month follow-up (self-reported). Any SAE or AE during supervised training sessions are registered by intervention providers. Participants are encouraged to contact the intervention providers or GP if a health problem occur. In case a medical evaluation is required, participants are referred to the Medical advisor (SSJ), who will decide if participation is safe. Exercise performance must be acceptable (i.e. pain or discomfort) to participants. If sudden joint-related pain flares beyond muscle soreness appear, exercises are regressed to fewer repetitions, sets or lower level until performance is acceptable. If one or more exercises are unacceptable regardless of regression, the exercise is not performed.	SAE and AE are registered at three- and six-month follow-up (self-reported). Participants are encouraged to contact the usual care providers or the GP if a health problem occurs. In case a medical evaluation is required, participants are referred to the medical advisor (SSJ), who decides if participation is safe.
WHERE	12	Exercises are performed unsupervised at home and at the supervised training sessions located in a fitness room at a University College in Denmark.	N/A
WHEN, HOW MUCH	13	Exercises should be performed three times a week over a period of six months. The exercises should be repeated minimum five times, be performed in sets of three and with a break of 15-30 seconds between each set.	N/A
TAILORING	14a	Exercises are tailored to each patient based upon response to the intervention through difficulty level, repetitions and acceptability. Patient education is tailored to each patient based on difficulties in everyday life, experiences, confidence and self-esteem.	Advice is tailored to each patient (i.e. difficulties in everyday life, experiences, confidence and self-esteem).
	14b	Exercises are individually tailored based on: (1) difficulty level (level C to A) and (2) repetitions. Moreover, (3) exercise performance has to be acceptable to participants with regard to pain and/or discomfort. Patient education is tailored based on: (1) pain and difficulties, (2) pain cooping, (3) preferred physical activities or sports and (4) BMI with respect to experiences, confidence and self-esteem.	Advice is tailored based on: (1) pain and difficulties, (2) pain cooping, (3) preferred physical activities or sports and (4) BMI with respect to experiences, confidence and self-esteem.
	15	The starting level of each difficulty level is: (1) correct performance, (2) performance is acceptable and (3) a minimum of five repetitions in sets of three can be completed.	N/A
HOW WELL	16a	Fidelity is registered by the intervention providers after finalisation of each patient. Fidelity describes to which extent the following categories were possible to deliver as intended: (1) Borg CR10 to determine difficulty level and repetitions, (2) patient acceptability to determine difficulty level and repetitions, (3) correct performance to determine difficulty level and repetitions, (4) patient education on rationale of regular exercise, physical activity and weight loss, if relevant.	N/A
	16b	N/A	N/A

Abbreviations: AE, adverse events; EARS, exercise adherence rating scale; GP, general practitioner; SAE, serious adverse events

Usual care (control)

Usual care will include one oral consultation provided by the PI on self-management of hip symptoms, including advice about staying physically active and exercising and, if relevant, advice to lose weight. Moreover, self-management of hip symptoms will include information about the hip morphology and advice to reduce symptoms by focusing on symptom-lowering activities and sports. The content of the information provided as usual care will be similar to the patient education provided to the participants in the intervention group. However, usual care will be limited to one session over six months and will not include instruction in specific hip exercises. In contrast, the participants in the intervention group will receive oral patient education in all supervised training sessions.

Adherence

Adherence to exercise and patient education will be self-reported and documented by weekly logbook recordings in the intervention group. At six-month follow-up, participants in the control group will be asked to report if they have performed specific hip exercises in the last month and how often and for how long (concomitant treatment). *High* adherence in the intervention group is defined as completing a minimum of 75% of scheduled training sessions (supervised and self-managed), *medium* adherence as completing 50-74%, and *low* adherence as completing less than 50%.[34] Acceptable adherence to exercise and patient education is defined as completing at least 70% of scheduled training sessions. Acceptable adherence to usual care is defined as completing less than 50% of similar training (e.g. concomitant treatment by own initiative). In addition, self-reported adherence to the intervention will be measured by the six-item Exercise Adherence Rating Scale (EARS).[35] The EARS measures non-adherence to complete adherence on a score of 0-24 points (24 highest score). Concomitant care will be registered.

Outcomes

At baseline, three-, six-, nine- and twelve-month follow-up, self-reported outcomes will be entered electronically by the participants using a survey option in REDCap (Table 2). The other outcomes will be collected at a clinical assessment at baseline and at six-month follow-up.

Primary outcome

The primary outcome will be the self-reported mean change in the pain subscale of the HAGOS from baseline to six-month follow-up (Figure 2). The HAGOS pain subscale measures the degree of hip and/or groin pain through ten questions.[36] The pain subscale has a high responsiveness, reported as effect sizes of 1.12-1.37.[36–38] The HAGOS is a valid and reliable outcome questionnaire, which is associated with correlation coefficients of 0.2-0.7 across subitems when correlated to relevant constructs.[36–38] The HAGOS consists of six subscales, including pain, symptoms, activities of daily living (ADL), sport and recreation (sport/rec), participation in physical activity (PA) and hip-related quality of life (QOL).[36] The measurement error ranges from 1 to 5 points across subscales at group level in patients with hip pain.[36,37,39]

Secondary outcomes

Secondary self-reported outcomes will be the mean change in the four remaining HAGOS subscales, i.e. symptoms, ADL, sport/rec, participation and QOL,[36] and the mean change in the score of the Short Version of the International Hip Outcome Tool (iHOT-12).[40]

Table 2: Baseline characteristics and outcome measures

Measure	Baseline	3 months	6 months	9 months	12 months
Patient characteristics					
Sex, age, height	X				
Weight	X		X		
Duration of hip symptoms	X				
Unilateral/bilateral affection	X				
Educational level, employment status, family status	X				
Comorbidities	X				
Previous surgery (ankle, knee, hip, back)	X				
Physical activity and exercise	X		X		X
FADIR test	X		X		
Radiological measures					
Center-edge angle	X				
Acetabular index angle	X				
Tönnis' osteoarthritis grade	X				
Self-reported measures					
Copenhagen Hip and Groin Outcome Score (HAGOS)	X	X	X	X	X
Short Version of the International Hip Outcome Tool (iHOT-12)	X		X		X
Patient Acceptable Symptom State (PASS)			X		X
Hip/groin pain intensity in rest within the last week on a VAS for pain	X		X		X
Hip/groin pain intensity in activity within the last week on a VAS for pain	X		X		X

Back pain intensity in rest within the last week on a VAS for pain	X		X		X
Back pain intensity in rest within the last week on a VAS for pain	X		X		X
Hip and/or groin pain intensity during hip flexion, extension and abduction strength tests on the Numeric Rating Scale for pain	X		X		
Usage of analgesics (y/n/type/dose)	X		X		X
European Quality of Life – 5 Dimensions with 5 Levels (EQ-5D-5L)	X	X	X	X	X
iMTA Productivity Cost Questionnaire (iPCQ)	X	X	X	X	X
Outcome measures on physical function (most painful hip)					
Single-leg Hop for Distance Test (HDT)	X		X		
Trust in capability of the hip during the HDT on a 100 mm VAS for trust	X		X		
Y-balance test, anterior, posteromedial and posterolateral	X		X		
Isometric hip muscle strength in flexion, extension and abduction with a fixed dynamometer	X		X		
Other treatment-related outcomes					
Iliopsoas and abductor-related muscle-tendon pain	X		X		
Pain sensitisation at the forearm and hip (temporal summation of pain and pressure pain threshold)	X		X		
Concomitant care and treatments[1]	X		X		X
Adverse events and serious adverse events		X	X		
Adherence to the intervention using the six-item Exercise Adherence Rating Scale (EARS)			X		
Adherence to intervention measured as number of completed training sessions	←	—	→		

[1]For baseline, concomitant care and treatments during the last year; for other time points, over the previous six months. Abbreviations: FADIR, Flexion-adduction-internal rotation test; iMTA, institute for Medical Technology Assessment; NRS, Numerical rating scale; VAS, Visual analogue Scale.

The iHOT-12 consists of 12 questions scored on a visual analogue scale from 0 points (worst) to 100 points (best). It is considered valid and reliable tool to measure change in young and active patients with hip disorders.[40]

Other secondary outcomes will be mean changes in performance, balance and maximal hip muscle strength (Supplementary material, performance, balance and muscle strength), which will be measured by two blinded outcome assessors in the most painful hip. The single-leg hop for distance test (HDT) is a measure of performance[41] (Supplementary Figure 1), and the Y Balance Test™ is a measure of dynamic balance[42] (Supplementary Figure 2). Maximal hip muscle strength will be measured isometrically in hip flexion, extension and abduction with a fixed dynamometer (Commander Echo MMT, JTECH Medical, Salt Lake City, UT, USA) using a standardised test protocol and external belt fixation[43,44] (Supplementary Figure 3). We will consider changes to be clinically relevant if they are above 0.15 Nm/kg in hip muscle strength,[44,45] above 15 cm in the Y Balance Test[46] and above 15 cm in HDT.[41]

Other outcomes

Health status will be measured with the EuroQoL 5-dimension (EQ-5D-5L),[49] and productivity loss will be measured with the Productivity Costs Questionnaire (IPCQ).[47]

Acceptable symptom state will be measured with the Patient Acceptable Symptom State (PASS)[48] by the question: "Taking into account all the activities you are doing in your daily life, your level of pain, and also your functional impairments, do you consider that your current state of symptoms is acceptable (yes/no)?"

Self-reported change in back and hip and/or groin pain intensity will be measured with a 100 mm Visual Analogue Scale (VAS) for pain in rest and during activity within the last week. Change in self-reported usage of analgesics will be registered, including usage of paracetamol/acetaminophen, ibuprofen and other NSAIDs and morphine/opioids.

Change in self-reported hip and/or groin pain intensity during the hip muscle strength tests will be measured using a numerical rating scale (NRS), and trust in the capability of the hip will be measured with a 100 mm VAS for trust during the HDT.[15]

The blinded outcome assessors will assess Iliopsoas- and abductor-related muscle-tendon pain[28] and pain sensitisation. Pain sensitisation will be measured as temporal summation of pain[52] and pressure pain threshold[53] at the hip and forearm.

Adverse events

Any serious adverse event (SAE) and adverse event (AE) related to the conduct of the trial within the intervention period will be reported to the local research ethics committee. SAEs will be defined according to the International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH).[49] AEs will be defined as sudden joint-related pain flares beyond muscle soreness in the hip/groin or other parts of the body. The intervention providers and test physical therapists will report any SAE and AE during training sessions or outcome assessments. Furthermore, at three- and six-month follow-up, participants will be asked to report any SAE or AE. In case a medical evaluation is required, participants will be referred to the hip surgeon (SSJ), who will decide if participation is safe.

Health-economic evaluation

A health-economic evaluation with 12-month follow-up will be conducted alongside the RCT to incorporate a societal perspective. Quality-adjusted life years (QALYs) will be the outcome in a cost-utility analysis, and the HAGOS pain will be the outcome in a cost-effectiveness analysis. QALYs will be calculated as the area under the curve using the EQ-5D-5L[50] and Danish preference weights.[51,52] Intervention costs will be calculated using micro-costing. Visits to primary health care services will be extracted from the Danish National Health Service Register for Primary Care (NHSR) and valued using the activity-based tariffs that are used for remuneration. Secondary health care services will be extracted from the National Patient Registry (NPR) and costs will be calculated using the associated diagnosis-related grouping tariff. The productivity costs per patient will be calculated using the Human Capital method and age and gender-matched average gross salaries from Statistics Denmark.

Incremental cost-effectiveness ratios (ICER) will be calculated by dividing the difference in costs by the difference in effects. The uncertainty around the ICER and 95% confidence intervals surrounding the cost differences will be estimated with 95% bootstrapped confidence intervals based on non-parametric bootstrapping (10,000 replicates)[53] and will be graphically presented on cost-effectiveness planes and cost-effectiveness acceptability curves (CEACs). These graphs will indicate if the intervention is cost-effective compared to usual care at different values of willingness to pay for a gain in outcome.

Process evaluation

A process evaluation will be conducted alongside the RCT to explore the functioning of the intervention by evaluating implementation, mechanisms of change and contextual factors.[54,55] Implementation includes the implementation process, fidelity, dose and reach (Supplementary Table 1). The implementation process will evaluate structures and resources through which delivery is achieved. Fidelity aspects will evaluate the extent to deliver each component as planned and registered during the intervention period using self-report questionnaires. Dose will evaluate how much intervention is delivered and registered during the intervention period using routine monitoring forms, and reach will be evaluated as patterns in uptake and adherence by baseline patient characteristics registered before and during the intervention period. Mechanisms of change

include interactions between the intervention, the intervention providers and the participants. Interactions will be evaluated through focus group interviews and by quantitative data on reasons for not receiving surgery. Contextual factors will include events, personal understandings and interactions and their possible influence on the implementation. Contextual factors will be evaluated through one-to-one semi-structured interviews during and after the intervention period. Findings from quantitative and quantitative analyses will be merged, interpretated and reported jointly. The results from the process evaluation will be used to refine the programme theory, including a logic model to be used in a potential full-scale implementation of the intervention (Supplementary Figure 4).

Long-term follow-up

Participants will be invited to complete the HAGOS and iHOT-12 after 2, 5 and 10 years to investigate predictors of long-term outcome and progression to hip-preserving surgery or hip replacement. In addition, we plan to evaluate if hip osteoarthritis progresses over 5 and 10 years by assessing the degree of osteoarthritis with the Tönnis osteoarthritis classification.[26]

Data management

Once a participant is enrolled, efforts will be made to collect all outcomes despite deviations from the intervention or usual care. All participants will receive a text-message reminder for the six-month follow-up assessment. If a patient is not able to attend or cancels the appointment, the patient will be offered to reschedule. If a patient does not attend the six-month follow-up assessment, the patient will be asked to complete the self-reported outcomes. Moreover, if a patient does not complete self-reported outcomes at any follow-up, one reminder will be sent. Reasons for dropping out and non-adherence to planned training sessions will be registered. All data collected in this trial is directly entered into REDCap for safe storage and will be treated confidentially by the research staff. The PI will perform checks of protocol adherence and data completeness. No formal data monitoring committee will be established. The authors will discuss any SAE yearly, classify these into subcategories and monitor recruitment, treatment and retention. No interim analysis will be performed.

Sample size

The power calculation was based on a clinical superiority calculation.[56] A minimal clinically important difference (MCID) of at least a 10-point between-group change in the HAGOS pain was the superiority margin over a six-month follow-up period.[37,39] Given a sample size of 200 participants (n=100 in each group), an alpha level of 2.5%, an MCID of at least a 10-point between-group change in the HAGOS pain and an expected between-group mean difference of a 15-point change in the HAGOS pain (standard deviation 13) over six months,[15] we will reach a power of 86%. Based on an expected dropout of 15% during the six-month period,[15] our sample size will be 170 participants (85 in each group), and the power of the trial will be 80%.

Statistical analysis

The intention-to-treat approach will be used for analysing all changes in primary and secondary outcome measures based on data from all enrolled participants according to randomisation group. For the primary outcome, between-group comparison from baseline to six-month follow-up will be analysed using a mixed-effects model with patient as a random factor and with time and allocation group as fixed factors. Parametric data with two time points will be analysed with the unpaired t-test, where categorical data will be analysed with the pseudo-observation method using risk difference as a measure of association (dichotomous).[57,58] All results will be presented with 95% confidence intervals and associated p values. A two-sided $p<0.05$ will be considered as statistically significant. A pre-specified statistical analysis plan will be made publicly available prior to inclusion of the final patient. The statistical analyses and the data interpretation will be blinded to group allocation. Data analysis will be performed with Stata 16) software package (StataCorp, College Station, TX, USA).

Ethics and dissemination

The trial will be conducted and reported in accordance with the WMA declaration of Helsinki, and the data will be handled in accordance with the General Data Protection Regulation. This trial has been approved by the Committee on Health Research Ethics in the Central Denmark Region (project ID: 1-10-72-336-20). The Danish Data Protection Agency authorised patient data handling (project ID: 1-16-02-678-20), and the study protocol has been registered at ClinicalTrials (trial identifier: NCT04795843). Any protocol amendments will be registered at ClinicalTrials, reported to the Committee on Health Research Ethics in the Central Denmark Region and addressed in the primary trial paper. Results will be published in international peer-reviewed scientific journals with open

access. Authorship will adhere to the Vancouver conventions as outlined by the International Committee of Medical Journal Editors.[59]

Explorative analyses

By using subgroup stratification, we will explore if muscle-tendon pain and pain sensitisation modify between-group changes of the primary and secondary outcomes over six months. Furthermore, we plan to conduct an instrumental variable analysis on primary and secondary outcomes in an attempt to investigate the efficacy of the intervention.[60] These analyses will be reported in secondary papers with clear reference to the primary trial paper.

Patient and public involvement

A qualitative study of 17 patients[14] and a feasibility study of 30 patients[15] collected information on expectations, needs and opinions about content, frequency and outcome of treatment as well as burden to participate. This information has been used to refine the intervention and the study procedures.

DISCUSSION

The majority of patients with hip dysplasia are treated non-surgically in primary care, and some data exists on changes after surgical treatment.[1,16,27,61–63] Nevertheless, there is limited evidence on what constitutes effective primary care for patients with hip dysplasia. By highlighting the benefits, harms, costs and processes of exercise and patient education, the MovetheHip trial will provide valuable evidence for patients, health professionals and decision-makers.

Strengths and limitations

The strengths of this trial are the preceding feasibility study[15] and the parallel health-economic and process-evaluation studies. Another strength is the development of a well-described flexible intervention designed to require little time to fit into the daily life of young to middle-aged patients, as this holds a potential for large-scale implementation.[14] Additional strengths are the use of assessor blinding and the randomised controlled design with blinded intention-to-treat analyses.

A limitation is that intervention providers and patients are not blinded to treatment allocation. However, blinded assessors will assess all clinical outcomes, and a blinded data analyst will perform all pre-defined analyses.

Moreover, the participants will be blinded to the trial hypotheses, and both participants and assessors will be blinded to previous testing scores at all follow-ups. Another limitation is the heterogeneity of the participants, which might make it difficult to show between-group differences. Finally, participants may choose various concomitant care, which may add to changes in outcomes. However, any concomitant care or treatment will be registered and reported as part of the health-economic evaluation.

AUTHORS' CONTRIBUTIONS

JSJ is the PI. IM, KT and JSJ designed the preliminary version of the present trial. RON contributed with methodological and statistical aspects, whereas DS and LGO provided input to the design of the intervention and to the design of the process evaluation study. LGO and MT contributed to the design of the health-economic evaluation. SSJ and CF provided imported insights on the clinical implication of the trial and recruited participants. All authors contributed to the drafting of this manuscript and approved the final version.

ACKNOWLEDGEMENTS

We would like to thank physical therapists Gitte Hjørnholm Madsen and Lene Boetker Nielsen from the Department of Physiotherapy and Occupational Therapy at Aarhus University Hospital, who were responsible for the baseline and six-month follow-up assessments. Furthermore, we would like to thank the intervention providers, Sofie Kristensen and Mikkel Gade, for delivering the exercise and patient education intervention, and the study coordinator, Ulla Gasseholm Baek, for supervising the intervention providers. Lastly, we would like to thank the Clinical Trials Unit from the Department of Clinical Medicine, Aarhus University, for data management support and access to REDCap.

FUNDING

This work was supported by the Danish foundation TrygFonden (grant number: 150195), the Danish Health Fund (grant number: 19-B-0170), the Danish Rheumatism Association (grant number: R175-A6011), Aase and Ejnar Danielsen's Foundation (N/A), the Research Foundation of the Association of Danish Physiotherapists (NA), the Fogh-Nielsen Legacy, Aarhus University (N/A), and the A.P. Moller Foundation (grant number: 20-L-0096).

COMPETING INTERESTS

None declared

PATIENT CONSENT FOR PUBLICATION

The person pictured in the supplementary Material has given consent for publication

ORCID IDS

Julie S Jacobsen: 0000-0002-3323-3631

Kristian Thorborg: 0000-0001-9102-4515

Rasmus Oestergaard Nielsen: 0000-0001-5757-1806

Stig Storgaard Jakobsen: 0000-0002-1890-3617

Casper Foldager: 0000-0001-8729-0810

Dorthe Sørensen: 0000-0001-6362-3385

Lisa Gregersen Oestergaard: 0000-0003-2255-1391

Maurits van Tulder: 0000-0002-7589-8471

Inger Mechlenburg: 0000-0001-5432-8691

REFERENCES

1 Mechlenburg I, Nyengaard JR, Rømer L, *et al.* Changes in load-bearing area after Ganz periacetabular osteotomy evaluated by multislice CT scanning and stereology. *Acta Orthop Scand* 2004;**75**:147–53. doi:10.1080/00016470412331294395

2 Gosvig KK, Jacobsen S, Sonne-Holm S, *et al.* Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: A population-based survey. *J Bone Jt Surg - Ser A* 2010;**92**:1162–9. doi:10.2106/JBJS.H.01674

3 Engesæter IØ, Laborie LB, Lehmann TG, *et al.* Prevalence of radiographic findings associated with hip dysplasia in a population-based cohort of 2081 19-year-old Norwegians. *Bone Joint J* 2013;**95-B**:279–85. doi:10.1302/0301-620X.95B2.30744

4 Birrell F. Syndrome of symptomatic adult acetabular dysplasia (SAAD syndrome). *Ann Rheum Dis* 2003;**62**:356–8. doi:10.1136/ard.62.4.356

5 Pun S. Hip dysplasia in the young adult caused by residual childhood and adolescent-onset dysplasia. *Curr Rev Musculoskelet Med* 2016;**9**:427–34. doi:10.1007/s12178-016-9369-0

6 Murphy SB, Ganz R, Müller ME. The prognosis in untreated dysplasia of the hip. A study of radiographic factors that predict the outcome. *J Bone Joint Surg Am* 1995;**77**:985–9. doi: 10.2106/00004623-199507000-00002

7 Clohisy JC, Dobson MA, Robison JF, *et al.* Radiographic structural abnormalities associated with premature, natural hip-joint failure. *J Bone Jt Surg - Ser A* 2011;**93**:3–9. doi:10.2106/JBJS.J.01734

8 Agricola R, Heijboer MP, Roze RH, *et al.* Pincer deformity does not lead to osteoarthritis of the hip whereas acetabular dysplasia does: Acetabular coverage and development of osteoarthritis in a nationwide prospective cohort study (CHECK). *Osteoarthr Cartil* 2013;**21**:1514–21. doi:10.1016/j.joca.2013.07.004

9 Wyles CC, Heidenreich MJ, Jeng J, *et al.* The John Charnley Award: Redefining the Natural History of Osteoarthritis in Patients With Hip Dysplasia and Impingement. *Clin Orthop Relat Res* 2017;**475**:336–50. doi:10.1007/s11999-016-4815-2

10 Clohisy JC, Ackerman J, Baca G, *et al.* Patient-reported outcomes of periacetabular osteotomy from the

prospective ANCHOR cohort study. *J Bone Jt Surg Am* 2017;**99**:33–41. doi:10.2106/JBJS.15.00798

11 Jashi R El, Gustafson MB, Jakobsen MB, *et al.* The association between gender and familial prevalence of hip dysplasia in danish patients. *HIP Int* 2017;**27**:299–304. doi:10.5301/hipint.5000461

12 Jacobsen JS, Søballe K, Thorborg K, *et al.* Patient-reported outcome and muscle–tendon pain after periacetabular osteotomy are related: 1-year follow-up in 82 patients with hip dysplasia. *Acta Orthop* 2019;**90**:40–5. doi:10.1080/17453674.2018.1555637

13 Boje J, Caspersen CK, Jakobsen SS, *et al.* Are changes in pain associated with changes in quality of life and hip function 2 years after periacetabular osteotomy? A follow-up study of 321 patients. *J Hip Preserv Surg* 2019;**6**:69–76. doi:10.1093/jhps/hnz009

14 Jorgensen MD, Frederiksen SB, Sørensen D, *et al.* Experiences of living with developmental dysplasia of the hip in adults not eligible for surgical treatment: a qualitative study. *BMJ Open* 2021;**11**:e052486. doi:10.1136/BMJOPEN-2021-052486

15 Jacobsen JS, Thorborg K, Sørensen D, *et al.* Feasibility and acceptability of exercise and patient education for patients with hip dysplasia over a six-month follow-up period. *Musculoskelet Sci Pract* 2022;**In review**.

16 Jacobsen JS, Jakobsen SS, Søballe K, *et al.* Isometric hip strength impairments in patients with hip dysplasia are improved but not normalized 1 year after periacetabular osteotomy: a cohort study of 82 patients. *Acta Orthop* 2021;:1–7. doi:10.1080/17453674.2020.1864911

17 Kuroda D, Maeyama A, Naito M, *et al.* Dynamic hip stability, strength and pain before and after hip abductor strengthening exercises for patients with dysplastic hips. *Isokinet Exerc Sci* 2013;**21**:95–100. doi:10.3233/IES-130480

18 Gambling T, Long AF. An exploratory study of young women adjusting to developmental dysplasia of the hip and deciding on treatment choices. *Chronic Illn* 2012;**8**:17–30. doi:10.1177/1742395311417638

19 Troelsen A, Elmengaard B, Søballe K. A new minimally invasive transsartorial approach for periacetabular osteotomy. *J Bone Joint Surg Am* 2008;**90**:493–8. doi:10.2106/JBJS.F.01399

20 Coobs BR, Xiong A, Clohisy JC. Contemporary Concepts in the Young Adult Hip Patient: Periacetabular

Osteotomy for Hip Dysplasia. *J Arthroplasty* 2015;**30**:1105–8. doi:10.1016/j.arth.2015.02.045

21 Novais EN, Potter GD, Clohisy JC, *et al.* Obesity is a major risk factor for the development of complications after peri-acetabular osteotomy. *Bone Joint J* 2015;**97-B**:29–34. doi:10.1302/0301-620X.97B1.34014

22 Jakobsen SS, Overgaard S, Søballe K, *et al.* The interface between periacetabular osteotomy, hip arthroscopy and total hip arthroplasty in the young adult hip. *EFORT Open Rev* 2018;**3**:408–17. doi:10.1302/2058-5241.3.170042

23 Chan AW, Tetzlaff JM, Altman DG, *et al.* SPIRIT 2013 Statement: defining standard protocol items for clinical trials. *Rev Panam Salud Publica* 2015;**38**:506–14. doi:10.7326/0003-4819-158-3-201302050-00583

24 Slade SC, Dionne CE, Underwood M, *et al.* Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *Br J Sports Med* 2016;**50**:1428–37. doi:10.1136/BJSPORTS-2016-096651

25 Wiberg G. Studies on Dysplastic Acetabula and Congenital Subluxation of the Hip Joint with Special References to the Complication of Osteoarthritis. *Acta Chir Scand Suppl* 1939;**58**:1–132.

26 Tönnis D. Congenital dysplasia and dislocation of the hip in children and adults. Berlin Heidelberg, New York: Springer 1987.

27 Jacobsen JS, Hölmich P, Thorborg K, *et al.* Muscle-tendon-related pain in 100 patients with hip dysplasia: prevalence and associations with self-reported hip disability and muscle strength. *J Hip Preserv Surg* 2018;**5**:39–46. doi:10.1093/jhps/hnx041

28 Jacobsen JS, Nielsen DB, Sørensen H, *et al.* Changes in walking and running in patients with hip dysplasia. *Acta Orthop* 2013;**84**:265–70. doi:10.3109/17453674.2013.792030

29 Mortensen L, Schultz J, Elsner A, *et al.* Progressive resistance training in patients with hip dysplasia: A feasibility study. *J Rehabil Med* 2018;**50**:751–8. doi:10.2340/16501977-2371

30 Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982;**14**:377–81.

31 Hartig-Andreasen C, Soballe K, Troelsen A. The role of the acetabular labrum in hip dysplasia. *Acta Orthop* 2013;**84**:60–4. doi:10.3109/17453674.2013.765626

32 Rausch Osthoff AK, Niedermann K, Braun J, *et al.* 2018 EULAR recommendations for physical activity in

people with inflammatory arthritis and osteoarthritis. *Ann Rheum Dis* 2018;**77**:1251–60. doi:10.1136/ANNRHEUMDIS-2018-213585

33 Li J, Siegrist J. Physical activity and risk of cardiovascular disease--a meta-analysis of prospective cohort studies. *Int J Environ Res Public Health* 2012;**9**:391–407. doi:10.3390/IJERPH9020391

34 Skou ST, Roos EM, Laursen MB, *et al.* Total knee replacement plus physical and medical therapy or treatment with physical and medical therapy alone: A randomised controlled trial in patients with knee osteoarthritis (the MEDIC-study). *BMC Musculoskelet Disord* 2012;**13**. doi:10.1186/1471-2474-13-67

35 Newman-Beinart NA, Norton S, Dowling D, *et al.* The development and initial psychometric evaluation of a measure assessing adherence to prescribed exercise: the Exercise Adherence Rating Scale (EARS). *Physiotherapy* 2017;**103**:180–5. doi:10.1016/j.physio.2016.11.001

36 Thorborg K, Hölmich P, Christensen R, *et al.* The Copenhagen Hip and Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. *Br J Sports Med* 2011;**45**:478–91. doi:10.1136/bjsm.2010.080937

37 Thomeé R, Jónasson P, Thorborg K, *et al.* Cross-cultural adaptation to Swedish and validation of the Copenhagen Hip and Groin Outcome Score (HAGOS) for pain, symptoms and physical function in patients with hip and groin disability due to femoro-acetabular impingement. *Knee Surgery, Sport Traumatol Arthrosc* 2014;**22**:835–42. doi:10.1007/s00167-013-2721-7

38 Stone A V, Jacobs CA, Luo TD, *et al.* High Degree of Variability in Reporting of Clinical and Patient-Reported Outcomes After Hip Arthroscopy. *Am J Sports Med* 2018;**46**:3040–6. doi:10.1177/0363546517724743

39 Kemp JL, Collins NJ, Roos EM, *et al.* Psychometric Properties of Patient-Reported Outcome Measures for Hip Arthroscopic Surgery. *Am J Sports Med* 2013;**41**:2065–73. doi:10.1177/0363546513494173

40 Griffin DR, Parsons N, Mohtadi NGH, *et al.* A short version of the International Hip Outcome Tool (iHOT-12) for use in routine clinical practice. *Arthrosc - J Arthrosc Relat Surg* 2012;**28**:611–8. doi:10.1016/j.arthro.2012.02.027

41 Kemp JL, Schache AG, Makdissi M, *et al.* Greater understanding of normal hip physical function may guide

clinicians in providing targeted rehabilitation programmes. *J Sci Med Sport* 2013;**16**. doi:10.1016/j.jsams.2012.11.887

42 Plisky PJ, Gorman PP, Butler RJ, *et al.* The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther* 2009;**4**:92–9.

43 Thorborg K, Petersen J, Magnusson SP, *et al.* Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scand J Med Sci Sports* 2010;**20**:493–501. doi:10.1111/j.1600-0838.2009.00958.x

44 Thorborg K, Bandholm T, Hölmich P. Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surgery, Sport Traumatol Arthrosc* 2013;**21**:550–5. doi:10.1007/s00167-012-2115-2

45 Krantz MM, Åström M, Drake AM. Strength and fatigue measurements of the hip flexor and hip extensor muscles: test-retest reliability and limb dominance effect. *Int J Sports Phys Ther* 2020;**15**:967–76. doi:10.26603/ijspt20200967

46 Linek P, Sikora D, Wolny T, *et al.* Reliability and number of trials of Y Balance Test in adolescent athletes. *Musculoskelet Sci Pract* 2017;**31**:72–5. doi:10.1016/j.msksp.2017.03.011

47 Bouwmans C, Krol M, Severens H, *et al.* The iMTA Productivity Cost Questionnaire. *Value Heal* 2015;**18**:753–8. doi:10.1016/j.jval.2015.05.009

48 Kvien TK, Heiberg T. Minimal clinically important improvement/difference (MCII/ MCID) and patient acceptable symptom state (PASS): what do these concepts mean? doi:10.1136/ard.2007.079798

49 International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human use (ICH). ICH harmonised guideline, integrated addendum, ICH E6(R1): Guideline for good clinical practice E6(R2). 2016. https://database.ich.org/sites/default/files/E6_R2_Addendum.pdf (accessed 8 Dec 2021).

50 Szende A, Janssen B, Cabasés J. *Self-reported population health: An international perspective based on EQ-5D*. Dordrecht Heidelberg New York London: SpringerOpen 2014. doi:10.1111/1744-7941.12100

51 Wittrup-Jensen KU, Lauridsen J, Gudex C, *et al.* Generation of a Danish TTO value set for EQ-5D health states. *Scand J Public Health* 2009;**37**:459–66. doi:10.1177/1403494809105287

52 Drummond MF, Sculpher MJ, Torrance GW, *et al.* Methods for the economic evaluation of health care programmes. Third edit. Oxford University Press 2005. https://books.google.co.uk/books?id=lvWACgAAQBAJ (accessed 20 Feb 2019).

53 Johnson RW. An Introduction to the Bootstrap. *Teach Stat* 2001;**23**:49–54. doi:10.1111/1467-9639.00050

54 Moore GF, Audrey S, Barker M, *et al.* Process evaluation of complex interventions: Medical Research Council guidance. *BMJ* 2015;**350**. doi:10.1136/bmj.h1258

55 Skivington K, Matthews L, Simpson SA, *et al.* A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ* 2021;**374**. doi:10.1136/BMJ.N2061

56 Chow S-C, Wang H, Shao J. *Sample Size Calculations in Clinical Research*. 2nd edition. New York 2007: Chapman and Hall/CRC 2007. doi:10.1201/9781584889830

57 Hansen SN, Andersen PK, Parner ET. Events per variable for risk differences and relative risks using pseudo-observations. *Lifetime Data Anal* 2014;**20**:584–98. doi:10.1007/s10985-013-9290-4

58 Kjaersgaard MIS, Parner ET. Instrumental variable method for time-to-event data using a pseudo-observation approach. *Biometrics* 2016;**72**:463–72. doi:10.1111/biom.12451

59 International Committee of Medical Journal Editors. Defining the Role of Authors and Contributors. http://www.icmje.org/recommendations/browse/roles-and-responsibilities/defining-the-role-of-authors-and-contributors.html (Accessed 28 03 2022).

60 Greenland S. An introduction to instrumental variables for epidemiologists. *Int J Epidemiol* 2000;**29**:722–9. doi:10.1093/ije/29.4.722

61 Fujita J, Doi N, Kinoshita K, *et al.* Rate of Return to Work After Periacetabular Osteotomy and Its Influencing Factors. *J Bone Joint Surg Am* Published Online First: 18 January 2022. doi:10.2106/JBJS.21.00548

62 Lerch TD, Steppacher SD, Liechti EF, *et al.* One-third of Hips After Periacetabular Osteotomy Survive 30 Years With Good Clinical Results, No Progression of Arthritis, or Conversion to THA. *Clin Orthop Relat Res* 2017;**475**:1154–68. doi:10.1007/s11999-016-5169-5

63 Hartig-Andreasen C, Troelsen A, Thillemann TM, *et al.* What factors predict failure 4 to 12 years after periacetabular osteotomy? *Clin Orthop Relat Res* 2012;**470**:2978–87. doi:10.1007/s11999-012-2386-4

FIGURES

Legend: Abbreviations: PAO, periacetabular osteotomy; HAGOS, Copenhagen Hip and Groin Outcome Score; BMI, Body mass index.

Caption: **Figure 1** Flow of participants through the trial.

Legend: The mean score of the intervention group (exercise and patient education) is anticipated to change from 60 to 80 points, corresponding to an improvement of 20 points over six months. In contrast, the mean score of the control group (usual care) is anticipated to change from 60 to 65 points, corresponding to an improvement of 5 points over six months. These group-based improvements lead to a hypothesised between-group change difference of 15 points (95% CI 10-20). The lower limit of the 95% CI between-group change difference of 10 points represents the minimal clinically important difference (MCIC), which is described in our hypothesis and included in our power calculation.

Caption: **Figure 2** Illustration of anticipated changes in the Copenhagen Hip and Groin Outcome Score (HAGOS) over a six-month follow-up period. Values are mean (95% CIs).

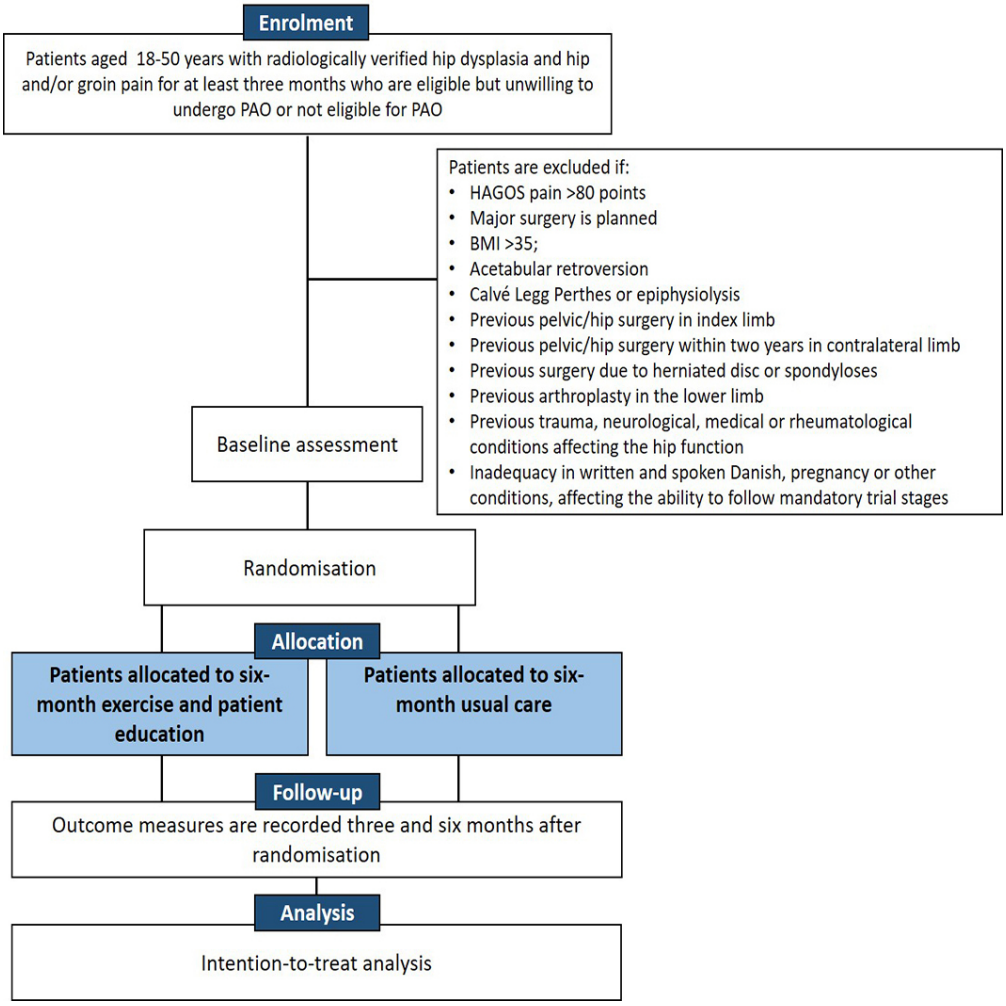


Figure 1 Flow of participants through the trial. Abbreviations: PAO, periacetabular osteotomy; HAGOS, Copenhagen Hip and Groin Outcome Score; BMI, Body mass index.

90x90mm (300 x 300 DPI)

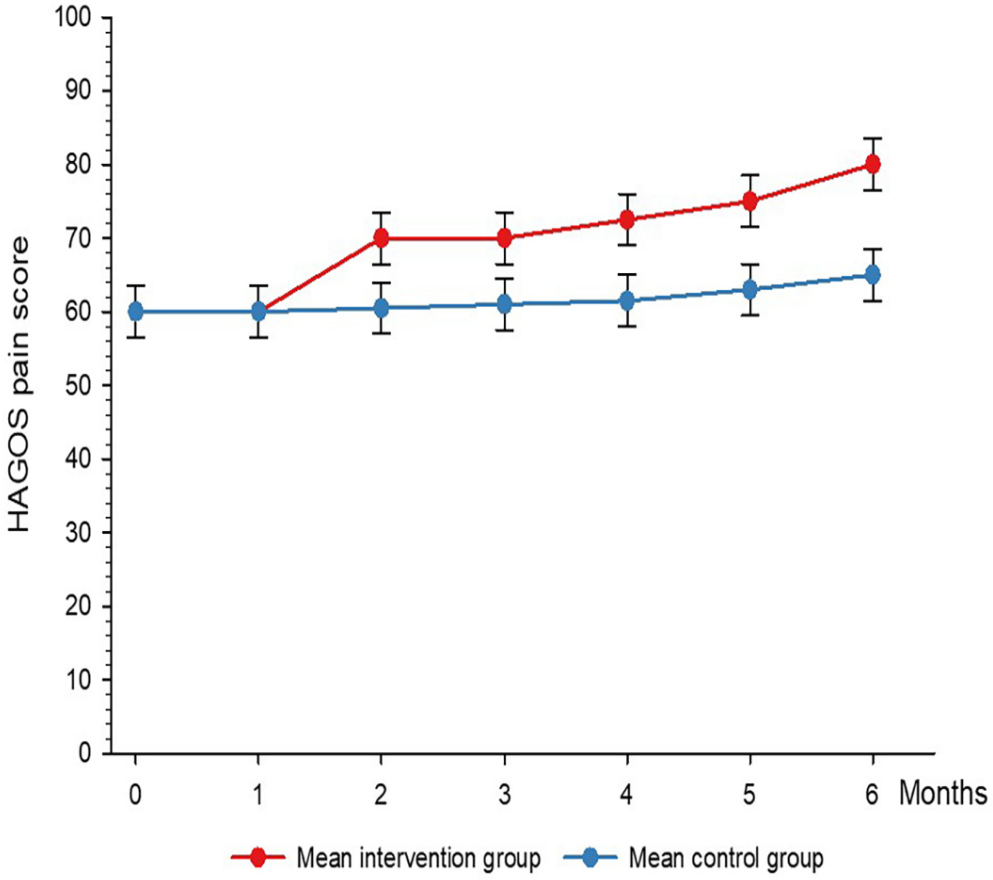
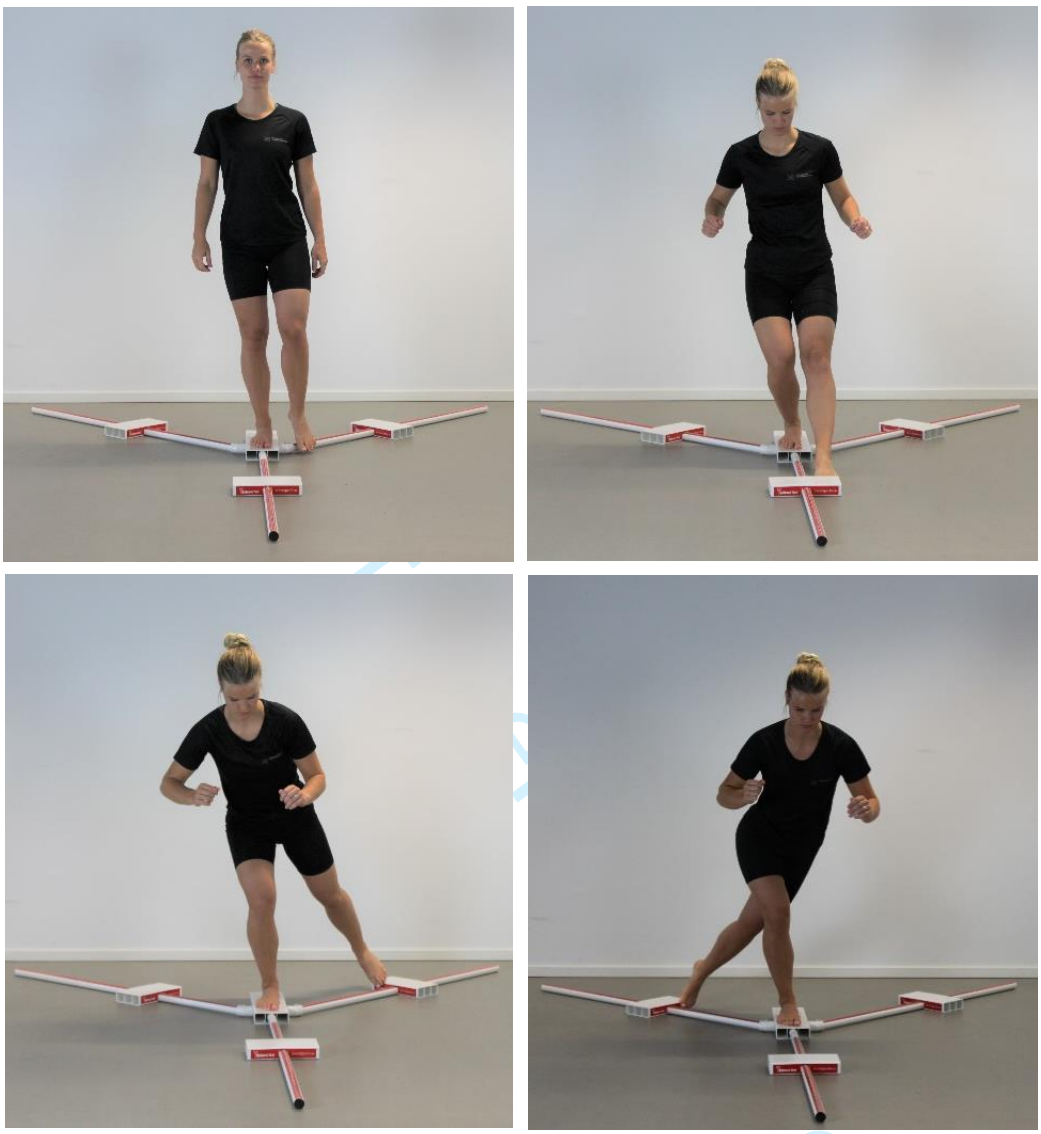


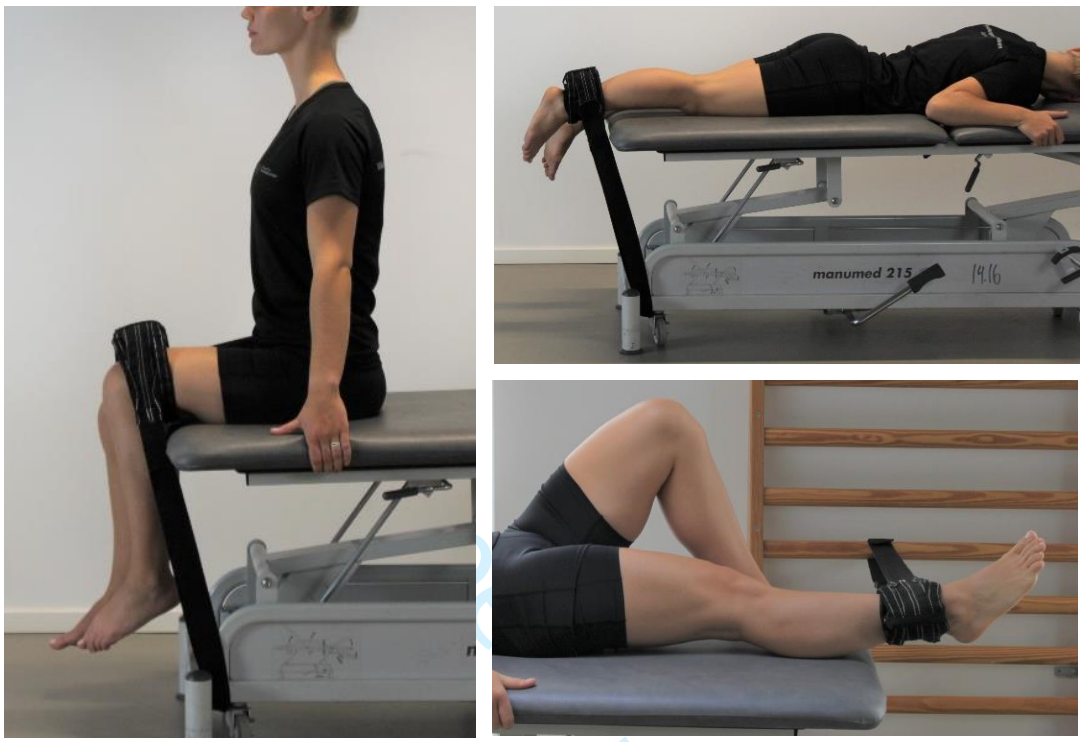
Figure 2 Illustration of anticipated changes in the Copenhagen Hip and Groin Outcome Score (HAGOS) over a six-month follow-up period. Values are mean (95% CIs). The mean score of the intervention group (exercise and patient education) is anticipated to change from 60 to 80 points, corresponding to an improvement of 20 points over six months. In contrast, the mean score of the control group (usual care) is anticipated to change from 60 to 65 points, corresponding to an improvement of 5 points over six months. These group-based improvements lead to a hypothesised between-group change difference of 15 points (95% CI 10-20). The lower limit of the 95% CI between-group change difference of 10 points represents the minimal clinically important difference (MCIC), which is described in our hypothesis and included in our power calculation.

90x90mm (300 x 300 DPI)

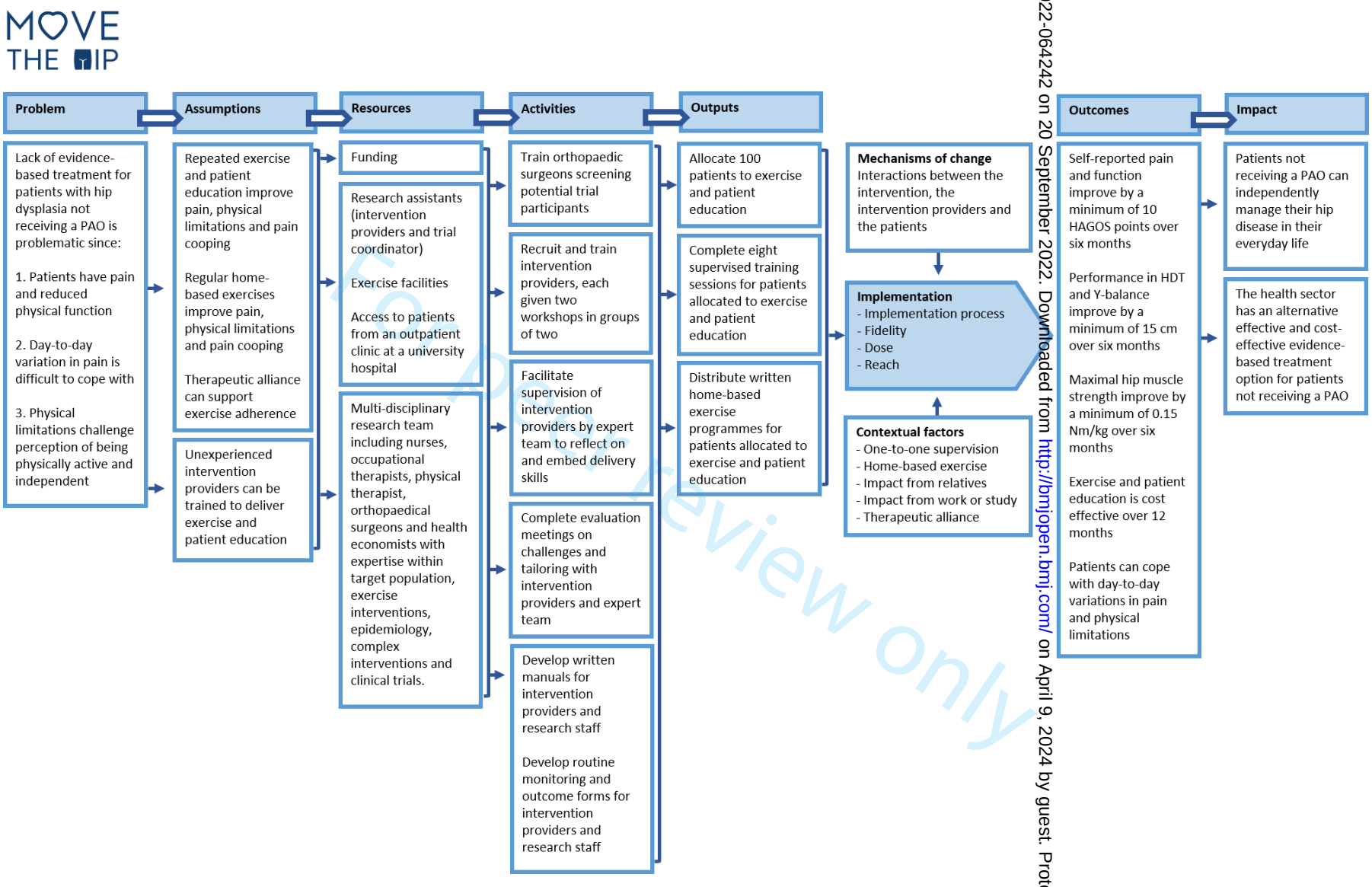
Supplementary Figure 1 Single-leg hop for distance test with both arms behind back.



Supplementary Figure 2 Y Balance test™. The figure illustrates the starting position (top left corner), the anterior, posteromedial and posterolateral reach (bottom right corner).



Supplementary Figure 3 Isometric hip muscle strength. The figure illustrates the testing procedure in flexion (left), extension (top right corner) and abduction (lower right corner) with external belt fixation



Supplementary Figure 4 Logic model for exercise and patient education in MovetheHip trial. Abbreviations: HAGOS, Copenhagen Hip and Groin Outcome Score; HDT, single-leg hop for distance test; PAO, periacetabular osteotomy.

MOVE THE HIP

Supplementary Table 1: Process evaluation of exercise and patient education: key dimensions and methods

Dimensions	Purpose	Data collection	Analysis
Fidelity	Evaluate to which extent the intervention is delivered as intended	Self-report questionnaires to evaluate to which extent the intervention providers could deliver specific content of the intervention using a 100 mm VAS from not possible (0) to always possible (100) on: 1. BORG CR10 to determine difficulty level and repetitions of exercises 2. Participants' acceptability to determine difficulty level and repetitions of exercises 3. Intervention manual to determine correct exercise performance 4. Delivery of patient education on pain mechanisms in hip dysplasia, advice on physical activity, weight loss and motivation and barriers for exercise adherence	Mean or median ability to deliver with associated variation
Dose	Evaluate how much of the intervention that is delivered	Data on number of completed exercise sessions (supervised and home-based session) and data on time used in each supervised exercise session using routine monitoring forms.	Number, median or mean dose with associated variation
Reach	Evaluate if patient characteristics differ between participants and non-participants	Data on sex, age and reason for not receiving a PAO are registered in participants and non-participants using standardised record forms.	Compare patient characteristics between participants and non-participants and different adherence groups
	Evaluate if patient characteristics differ between adherence groups	Data on patient characteristics (i.e. age, BMI, family status, education, CE angle, Tönnis osteoarthritis score, back and hip/groin pain intensity, etc.) are registered in adherent and non-adherent participants using standardised record forms.	

Mechanisms of change	Evaluate possible modifying mechanisms on the implementation	One-to-one semi-structured interviews during and at six-month follow-up in 15-20 participants. The interviews focus on previous exercise experiences and expectations to the intervention. They also focus on satisfaction and adaptations following the intervention. Semi-structured focus group interviews with the intervention providers and the expert team. The interviews focus on interactions between the intervention, the intervention providers and the participants in terms of challenges and tailoring based on responses and observations from individual participants.	Theory-driven content analysis
		Reasons for not receiving a PAO, dichotomised into “not offered PAO” (group 1) or “not willing to undergo PAO" (group 2), are registered using standardised record forms.	Compare adherence between groups over six months
Context	Understand the contribution of contextual factors on the implementation	One-to-one semi-structured interviews at baseline and at six-month follow-up in 15-20 participants in the intervention group. These will focus on the contribution of contextual factors on the implementation.	Theory-driven content analysis

Abbreviations: CE angle, centre-edge angle; CR, category ratio-scale; PAO, periacetabular osteotomy; VAS, visual analogue scale.

MOVE THE HIP

THE HOP FOR DISTANCE TEST

Standing barefoot behind a starting line, the participants are asked to hop as far as possible on the leg of the most painful hip and to land on the same foot, with both arms behind the back [2] (Supplementary Figure 1). The length of the best out of three attempts is measured from the starting line to the posterior aspect of the heel of the landing foot. The hop distance is measured in centimetres with inflexible measuring tape and normalised to height [1]. An attempt is discarded and repeated if balance cannot be maintained for 2-3 seconds after landing. If the participant improves more than 10 centimetres between the second and third hop, additional hops are performed until an increase of less than 10 centimetres is measured. Prior to the test, the outcome assessors will demonstrate how the test should be performed, and the participants are given two practice tests. The intra-rater reliability has been reported as excellent (standard error of measurement (SEM) is 3 centimetres, and the intra-class correlation coefficient (ICC) is 0.98) [1].

THE Y BALANCE TEST™

The Y balance test kit™ (PhysioSupplies, Groningen, Netherlands) is used (Supplementary Figure 2), and a reliable test protocol will be followed [3]. While maintaining single leg stance on the leg of the most painful hip, the participants are instructed to stand on the leg in the centre of the platform behind the red line. The participants are instructed to reach with the free limb in the anterior direction for three attempts, followed by three attempts in the posteromedial direction and then three trials in posterolateral direction, all named in relation to the stance foot. The participants are instructed to push the distance indicator as far as possible in each direction and return to the starting position (single leg stance). The entire surface of the foot must remain in contact with the platform throughout the entire duration of the movement. The maximal reach distance of the three attempts for each reach is measured down to half a centimetre. The maximal reach distance is normalised to limb length by dividing reach distance with limp length (anterior superior iliac spine to the most distal portion of the medial malleolus). The greatest reach distances for each of the directions are summed to yield a composite reach distance. An attempt will be discarded and repeated if: 1) the unilateral stance fails, 2) contact with the reach indicator fails, 3) the reach indicator is used for stance support, 4) the reach foot is not returned to the starting position under control or 5) the heel on the platform is lifted. Prior to the test, each participant will be given six practice tests in each direction. The intra-rater reliability has been reported as excellent (standard error of measurement (SEM) is 2-3 centimetres, and the intra-class correlation coefficient (ICC) is 0.85-0.98) [3].

MOVE THE HIP

ISOMETRIC HIP MUSCLE STRENGTH TEST

Hip muscle strength is measured isometrically with a dynamometer (Commander Echo MMT, JTECH Medical, Salt Lake City, UT, USA) in the most painful hip using an external belt fixation [5] (Supplementary Figure 3). A reliable test protocol will be followed [4]. Hip muscle strength is measured with a make test in hip flexion, extension and abduction (in a random order). The test positions are sitting for hip flexion, prone for hip extension and supine for hip abduction. The participants are instructed to exert a five-second maximum voluntary contraction against the dynamometer. The best out of four attempts in each direction will be registered together with torque as Nm/kg by multiplying with limb length and dividing by body weight. In hip extension and abduction, limb length is measured from the anterior superior iliac spine to five centimetres proximal to the lateral malleolus. In hip flexion, limb length is measured from the anterior superior iliac spine to five centimetres proximal to the basis of patella. Prior to tests, participants will be given two practice submaximal contractions; one into the tester´s hand and another against the dynamometer. The inter-rater reliability has been reported as good (standard error of measurement (SEM) is 0.12-0.25Nm/kg, and the intra-class correlation coefficient (ICC) is 0.72-0.92) [6].

MOVE THE HIP

REFERENCES

1 Kemp JL, Schache AG, Makdissi M, *et al.* Greater understanding of normal hip physical function may guide clinicians in providing targeted rehabilitation programmes. *J Sci Med Sport* 2013;**16**. doi:10.1016/j.jsams.2012.11.887

2 Ageberg E, Cronström A. Agreement between test procedures for the single-leg hop for distance and the single-leg mini squat as measures of lower extremity function. *BMC Sports Sci Med Rehabil* 2018;**10**:15. doi:10.1186/s13102-018-0104-6

3 Plisky PJ, Gorman PP, Butler RJ, *et al.* The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther* 2009;**4**:92–9.

4 Thorborg K, Petersen J, Magnusson SP, *et al.* Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scand J Med Sci Sports* 2010;**20**:493–501. doi:10.1111/j.1600-0838.2009.00958.x

5 Thorborg K, Bandholm T, Hölmich P. Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surgery, Sport Traumatol Arthrosc* 2013;**21**:550–5. doi:10.1007/s00167-012-2115-2

6 Jacobsen JS, Hölmich P, Thorborg K, *et al.* Muscle-tendon-related pain in 100 patients with hip dysplasia: prevalence and associations with self-reported hip disability and muscle strength. *J Hip Preserv Surg* 2018;**5**:39–46. doi:10.1093/jhps/hnx041

SPIRIT 2013 Checklist: Recommended items to address in a clinical trial protocol and related documents*

Section/item	Item No	Description	Addressed on page number
Administrative information			
Title	1	Descriptive title identifying the study design, population, interventions, and, if applicable, trial acronym	1
Trial registration	2a	Trial identifier and registry name. If not yet registered, name of intended registry	3, 19
	2b	All items from the World Health Organization Trial Registration Data Set	19
Protocol version	3	Date and version identifier	N/A
Funding	4	Sources and types of financial, material, and other support	21
Roles and responsibilities	5a	Names, affiliations, and roles of protocol contributors	1, 20
	5b	Name and contact information for the trial sponsor	N/A
	5c	Role of study sponsor and funders, if any, in study design; collection, management, analysis, and interpretation of data; writing of the report; and the decision to submit the report for publication, including whether they will have ultimate authority over any of these activities	N/A
	5d	Composition, roles, and responsibilities of the coordinating centre, steering committee, endpoint adjudication committee, data management team, and other individuals or groups overseeing the trial, if applicable (see Item 21a for data monitoring committee)	17-18

Introduction			
Background and rationale	6a	Description of research question and justification for undertaking the trial, including summary of relevant studies (published and unpublished) examining benefits and harms for each intervention	3, 5-6
	6b	Explanation for choice of comparators	5
Objectives	7	Specific objectives or hypotheses	5-6
Trial design	8	Description of trial design including type of trial (eg, parallel group, crossover, factorial, single group), allocation ratio, and framework (eg, superiority, equivalence, noninferiority, exploratory)	6
Methods: Participants, interventions, and outcomes			
Study setting	9	Description of study settings (eg, community clinic, academic hospital) and list of countries where data will be collected. Reference to where list of study sites can be obtained	6-7
Eligibility criteria	10	Inclusion and exclusion criteria for participants. If applicable, eligibility criteria for study centres and individuals who will perform the interventions (eg, surgeons, psychotherapists)	7
Interventions	11a	Interventions for each group with sufficient detail to allow replication, including how and when they will be administered	8-12
	11b	Criteria for discontinuing or modifying allocated interventions for a given trial participant (eg, drug dose change in response to harms, participant request, or improving/worsening disease)	10-11, 16
	11c	Strategies to improve adherence to intervention protocols, and any procedures for monitoring adherence (eg, drug tablet return, laboratory tests)	8,12
	11d	Relevant concomitant care and interventions that are permitted or prohibited during the trial	12
Outcomes	12	Primary, secondary, and other outcomes, including the specific measurement variable (eg, systolic blood pressure), analysis metric (eg, change from baseline, final value, time to event), method of aggregation (eg, median, proportion), and time point for each outcome. Explanation of the clinical relevance of chosen efficacy and harm outcomes is strongly recommended	12-15
Participant timeline	13	Time schedule of enrolment, interventions (including any run-ins and washouts), assessments, and visits for participants. A schematic diagram is highly recommended (see Figure)	6-8

Sample size	14	Estimated number of participants needed to achieve study objectives and how it was determined, including clinical and statistical assumptions supporting any sample size calculations	18
Recruitment	15	Strategies for achieving adequate participant enrolment to reach target sample size	6
Methods: Assignment of interventions (for controlled trials)			
Allocation:			
Sequence generation	16a	Method of generating the allocation sequence (eg, computer-generated random numbers), and list of any factors for stratification. To reduce predictability of a random sequence, details of any planned restriction (eg, blocking) should be provided in a separate document that is unavailable to those who enrol participants or assign interventions	7
Allocation concealment mechanism	16b	Mechanism of implementing the allocation sequence (eg, central telephone; sequentially numbered, opaque, sealed envelopes), describing any steps to conceal the sequence until interventions are assigned	7
Implementation	16c	Who will generate the allocation sequence, who will enrol participants, and who will assign participants to interventions	7
Blinding (masking)	17a	Who will be blinded after assignment to interventions (eg, trial participants, care providers, outcome assessors, data analysts), and how	7-8
	17b	If blinded, circumstances under which unblinding is permissible, and procedure for revealing a participant's allocated intervention during the trial	7-8
Methods: Data collection, management, and analysis			
Data collection methods	18a	Plans for assessment and collection of outcome, baseline, and other trial data, including any related processes to promote data quality (eg, duplicate measurements, training of assessors) and a description of study instruments (eg, questionnaires, laboratory tests) along with their reliability and validity, if known. Reference to where data collection forms can be found, if not in the protocol	8, 12-18, Supplementary material
	18b	Plans to promote participant retention and complete follow-up, including list of any outcome data to be collected for participants who discontinue or deviate from intervention protocols	17-18

Data management	19	Plans for data entry, coding, security, and storage, including any related processes to promote data quality (eg, double data entry; range checks for data values). Reference to where details of data management procedures can be found, if not in the protocol	17-18
Statistical methods	20a	Statistical methods for analysing primary and secondary outcomes. Reference to where other details of the statistical analysis plan can be found, if not in the protocol	18-19
	20b	Methods for any additional analyses (eg, subgroup and adjusted analyses)	19
	20c	Definition of analysis population relating to protocol non-adherence (eg, as randomised analysis), and any statistical methods to handle missing data (eg, multiple imputation)	19
Methods: Monitoring			
Data monitoring	21a	Composition of data monitoring committee (DMC); summary of its role and reporting structure; statement of whether it is independent from the sponsor and competing interests; and reference to where further details about its charter can be found, if not in the protocol. Alternatively, an explanation of why a DMC is not needed	17-18
	21b	Description of any interim analyses and stopping guidelines, including who will have access to these interim results and make the final decision to terminate the trial	18
Harms	22	Plans for collecting, assessing, reporting, and managing solicited and spontaneously reported adverse events and other unintended effects of trial interventions or trial conduct	16
Auditing	23	Frequency and procedures for auditing trial conduct, if any, and whether the process will be independent from investigators and the sponsor	18
Ethics and dissemination			
Research ethics approval	24	Plans for seeking research ethics committee/institutional review board (REC/IRB) approval	19
Protocol amendments	25	Plans for communicating important protocol modifications (eg, changes to eligibility criteria, outcomes, analyses) to relevant parties (eg, investigators, REC/IRBs, trial participants, trial registries, journals, regulators)	19

Consent or assent	26a	Who will obtain informed consent or assent from potential trial participants or authorised surrogates, and how (see Item 32)	6-7
	26b	Additional consent provisions for collection and use of participant data and biological specimens in ancillary studies, if applicable	N/A
Confidentiality	27	How personal information about potential and enrolled participants will be collected, shared, and maintained in order to protect confidentiality before, during, and after the trial	17-18
Declaration of interests	28	Financial and other competing interests for principal investigators for the overall trial and each study site	21
Access to data	29	Statement of who will have access to the final trial dataset, and disclosure of contractual agreements that limit such access for investigators	8
Ancillary and post-trial care	30	Provisions, if any, for ancillary and post-trial care, and for compensation to those who suffer harm from trial participation	N/A
Dissemination policy	31a	Plans for investigators and sponsor to communicate trial results to participants, healthcare professionals, the public, and other relevant groups (eg, via publication, reporting in results databases, or other data sharing arrangements), including any publication restrictions	3,19
	31b	Authorship eligibility guidelines and any intended use of professional writers	19
	31c	Plans, if any, for granting public access to the full protocol, participant-level dataset, and statistical code	18-19
Appendices			
Informed consent materials	32	Model consent form and other related documentation given to participants and authorised surrogates	N/A
Biological specimens	33	Plans for collection, laboratory evaluation, and storage of biological specimens for genetic or molecular analysis in the current trial and for future use in ancillary studies, if applicable	N/A

*It is strongly recommended that this checklist be read in conjunction with the SPIRIT 2013 Explanation & Elaboration for important clarification on the items. Amendments to the protocol should be tracked and dated. The SPIRIT checklist is copyrighted by the SPIRIT Group under the Creative Commons "Attribution-NonCommercial-NoDerivs 3.0 Unported" license.

BMJ Open

Protocol: Comparing exercise and patient education with usual care in the treatment of hip dysplasia: a randomised controlled trial with six-month follow-up (MovetheHip trial)

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-064242.R1
Article Type:	Protocol
Date Submitted by the Author:	15-Aug-2022
Complete List of Authors:	Jacobsen, Julie; Research Unit for General Practice; VIA University College, Research Centre for Health and Welfare Technology, Programme for Rehabilitation Thorborg, Kristian; Copenhagen University Hospital, Amager-Hvidovre, Sports Orthopaedic Research Center-Copenhagen (SORC-C), Department of Orthopaedic Surgery; Copenhagen University Hospital, Amager-Hvidovre, Physical Medicine and Rehabilitation Research-Copenhagen (PMR-C), Department of Physical and Occupational Therapy Nielsen, Rasmus; Aarhus University, Department of Public Health; Research Unit for General Practice Jakobsen, SS; Aarhus University Hospital, Department of Orthopaedic Surgery; Aarhus University, Department of Clinical Medicine Foldager, C; Aarhus University Hospital, Department of Orthopaedic Surgery Sørensen, Dorthe; VIA University College, Research Centre for Health and Welfare Technology, Programme for Rehabilitation Oestergaard, Lisa; Defactum, Central Denmark Region; Aarhus University Hospital, Department of Occupational Therapy and Physiotherapy van Tulder, Maurits; Vrije Universiteit Amsterdam, Department of Human Movement Sciences, Faculty of Behavioural and Movement Sciences Mechlenburg, Inger; Aarhus University Hospital, Department of Orthopaedic Surgery; Aarhus University, Department of Clinical Medicine
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Rehabilitation medicine
Keywords:	Hip < ORTHOPAEDIC & TRAUMA SURGERY, Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY, SPORTS MEDICINE, REHABILITATION MEDICINE

PROTOCOL: COMPARING EXERCISE AND PATIENT EDUCATION WITH USUAL CARE IN THE TREATMENT OF HIP DYSPLASIA: A RANDOMISED CONTROLLED TRIAL WITH SIX-MONTH FOLLOW-UP (MOVETHEHIP TRIAL)

Authors

Julie Sandell Jacobsen[1,2], Kristian Thorborg[3,4], Rasmus Oestergaard Nielsen[2,5], Stig Storgaard Jakobsen[6,7], Casper Foldager[6], Dorthe Sørensen[1], Lisa Gregersen Oestergaard[5,8,9], Maurits W van Tulder[9,10], Inger Mechlenburg[5,6,7]

Affiliations

[1]Research Centre for Health and Welfare Technology, Programme for Rehabilitation, VIA University College, Aarhus, Denmark

[2]Research Unit for General Practice, Aarhus, Denmark

[3]Sports Orthopaedic Research Center-Copenhagen (SORC-C), Department of Orthopaedic Surgery, Copenhagen University Hospital, Amager-Hvidovre, Hvidovre, Denmark

[4]Physical Medicine and Rehabilitation Research-Copenhagen (PMR-C), Department of Physical and Occupational Therapy, Copenhagen University Hospital, Amager-Hvidovre, Hvidovre, Denmark

[5]Department of Public Health, Aarhus University, Aarhus, Denmark

[6]Department of Orthopaedic Surgery, Aarhus University Hospital, Aarhus, Denmark

[7]Department of Clinical Medicine, Aarhus University, Aarhus, Denmark

[8]DEFACTUM, Central Denmark Region, Aarhus, Denmark

[9]Department of Occupational Therapy and Physiotherapy, Aarhus University Hospital, Aarhus, Denmark

[10]Department of Human Movement Sciences, Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Netherlands

Corresponding author

Julie Sandell Jacobsen, Research Centre for Health and Welfare Technology, Programme for Rehabilitation, VIA University College, Hedeager 2, 8200 Aarhus N, Denmark. E-mail: jsaj@via.dk

Word count: 3,937 words

ABSTRACT

Introduction

Surgery is not a viable treatment for all patients with hip dysplasia. Currently, usual care for these patients is limited to a consultation on self-management. We have shown that an exercise and patient education intervention is a feasible and acceptable intervention for patients not receiving surgery. Therefore, we aim to investigate if patients with hip dysplasia randomised to exercise and patient education have a different mean change in self-reported pain compared with those randomised to usual care over six months. Furthermore, we aim to evaluate the cost-effectiveness and perform a process evaluation.

Methods and analysis

In a randomised controlled trial, 200 young and middle-aged patients will be randomised to either exercise and patient education or usual care at a 1:1 ratio through permuted block randomisation. The intervention group will receive exercise instruction and patient education over six months. The usual care group will receive one consultation on self-management of hip symptoms. The primary outcome is the self-reported mean change in the pain subscale of the Copenhagen Hip and Groin Outcome Score (HAGOS). Secondary outcomes include mean changes in the other HAGOS subscales, in the Short Version of the International Hip Outcome Tool (iHOT-12), in performance, balance and maximal hip muscle strength. Between-group comparison from baseline to six-month follow-up will be made with intention-to-treat analyses with a mixed-effects model. Cost-effectiveness will be evaluated by relating quality-adjusted life years and differences in HAGOS pain to differences in costs over 12 months. The functioning of the intervention will be evaluated as implementation, mechanisms of change and contextual factors.

Ethics and dissemination

The study protocol was approved by the Committee on Health Research Ethics in the Central Denmark Region and registered at ClinicalTrials. Positive, negative and inconclusive findings will be disseminated through international peer-reviewed scientific journals and international conferences.

Trial registration number: NCT04795843

Keywords

Hip < ORTHOPAEDIC & TRAUMA SURGERY, Musculoskeletal disorders < ORTHOPAEDIC & TRAUMA SURGERY, SPORTS MEDICINE, REHABILITATION MEDICINE

STRENGTHS AND LIMITATIONS OF THIS TRIAL

- This trial is the first to compare exercise and patient education with usual care in patients with hip dysplasia.
- A feasibility study including qualitative and quantitative data preceded this trial.
- The investigation includes a clinical evaluation, a health-economic evaluation and a process evaluation.
- The intervention is designed to fit into the patients' everyday life with a potential for large-scale use.
- A limitation of this trial is the inability to blind participants and intervention providers.

INTRODUCTION

Hip dysplasia is the medical term for a hip joint with a reduced acetabular weight-bearing area.[1] The prevalence proportion of radiographic findings is 3-20% in the general population[2,3] and 19-32% in adults with hip pain.[2,4] Hip dysplasia can present in infancy or in young adulthood,[5] and hip dysplasia is associated with early osteoarthritis.[6–9] The joint disease affects mainly young to middle-aged women,[10] and many have a familial predisposition.[11] The most common symptom is groin pain, which is associated with high day-to-day variation in pain intensity,[10,12,13] and this unpredictability is perceived as the most challenging aspect to cope with.[14]

Young and middle-aged adults with hip dysplasia are often exposed to daily physical demands due to occupational and family-related responsibilities.[15] Physical limitations imposed by hip problems challenge their perception of being physically active and independent, which may affect their personal identity, confidence and self-esteem.[10,14,16–18] This bio-psycho-social impact of hip dysplasia call for effective and individualised treatment options.[14] Periacetabular osteotomy (PAO) is a well-accepted surgical treatment for patients with pain.[19] Yet, a PAO is not always a viable treatment option for all patients. Patients with a BMI above 25, age above 45 years or hip osteoarthritis may not be offered a PAO since worse outcomes are associated with these characteristics.[20–22] Besides, a subgroup of the patients offered a PAO are not willing to undergo surgery. Currently, usual care for these patients is limited to a single consultation on self-management of hip symptoms.

We recently completed a feasibility study on an exercise and patient education intervention for patients not receiving a PAO. The results showed a high willingness to be recruited and acceptable retention. We found clinical relevant improvements in pain, physical function and maximum hip muscle strength with a high intervention acceptance.[15] The feasibility study contributed to refinement of the intervention, the data collection and the recruitment procedures. Thus, it seems feasible to conduct a full-scale randomised controlled trial (RCT) to investigate the effectiveness of exercise and patient education on pain, physical functioning and maximum hip muscle strength.

The primary aim of this effectiveness trial is to investigate if patients with hip dysplasia who are randomised to exercise and patient education have a different mean change in self-reported pain measured by the Copenhagen

Hip and Groin Outcome Score (HAGOS) compared with those randomised to usual care over a six-month follow-up period. Secondary aims are to compare mean changes between the two groups on the other HAGOS subscales over a six-month follow-up period. Similar comparisons will be made on self-reported mean changes in the Short Version of the International Hip Outcome Tool (iHOT-12) and mean changes in performance, balance and maximum hip muscle strength. We hypothesise that patients randomised to exercise and patient education will have a between-group mean change score on the HAGOS pain that is at least 10 points higher than those randomised to usual care over a six-month follow-up period.

In a health-economic evaluation, we will investigate the cost-utility and cost-effectiveness of exercise and patient education compared with usual care over 12 months. Furthermore, in a process evaluation, we will explore the functioning of the intervention by evaluating the implementation, mechanisms of change and the contribution of contextual factors over six months.

METHODS AND ANALYSIS

Trial design

This study is a parallel-group superiority RCT following the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) statement.[23] The treatments are described according to the Consensus on Exercise Reporting Template (CERT).[24] Permuted block randomisation will be used with a 1:1 ratio with the primary end-points after six months. The first participant was enrolled in April 2021, and enrolment is expected to be completed by December 2025.

Study setting

We will recruit participants from the Department of Orthopaedic Surgery at Aarhus University Hospital in Denmark. Orthopaedic surgeons, specialised in hip dysplasia, will apply eligibility criteria and will provide oral and written information to patients with hip dysplasia as part of an initial screening. Following an initial screening, the principal investigator (PI) will contact patients willing to participate by phone and will verify the eligibility criteria. The PI will provide detailed oral information about the trial objective, clinical implication, procedures, funding and possible adverse events. Following this, the PI will obtain informed consent by sending a personal electronic letter to the

individual patient's eBoks, which is a national secure electronic mailbox for encrypted digital communication between citizens, private companies and public authorities in Denmark.

Eligibility criteria

Inclusion criteria: (1) 18-50 years of age; (2) radiographically verified hip dysplasia (Wiberg's center edge (CE) angle of 10-25 degrees[25] and an acetabular index (AI) angle >10 degrees[26]); (3) hip and/or groin pain (primary pain complain) for at least three months; (4) eligible but unwilling to undergo PAO or not eligible for PAO (negative impingement test, BMI >25, Tönnis hip osteoarthritis score >1, age >45 years or reduced hip range of motion (<95° flexion or <30° abduction)). Exclusion criteria: (1) HAGOS pain score >80 points; (2) any major planned surgery (arthroplasty or discectomy surgery); (3) BMI >35; (4) acetabular retroversion defined by crossover sign and posterior wall sign; (5) Calvé Legg Perthes or epiphysiolysis; (6) previous pelvic/hip surgery in index limb; (7) previous pelvic/hip surgery within two years in contralateral limb; (8) previous surgery due to herniated disc or spondyloses; (9) previous arthroplasty in the lower limb; (10) previous trauma, neurological, medical or rheumatological conditions affecting the hip function; (11) inadequacy in written and spoken Danish, pregnancy, mental illness or other conditions affecting the ability to follow mandatory stages for participation.

Randomisation

Following enrolment and a baseline assessment, participants will be randomised to exercise and patient education or usual care at a 1:1 ratio through permuted block randomisation with randomly varying block sizes of 4 to 6 (Figure 1). An independent data manager will set up a computer-generated list of random numbers in the Research Electronic Data Capture (REDCap) randomisation system before the inclusion of participants. The group allocation will be concealed since a research assistant not involved in the outcome assessment will perform the randomisation without being able to foresee the group assignment. The research assistant will inform the PI about the group allocation, and the PI will assign participants to one of the two groups. The participants will start treatment closely thereafter.

Blinding

Neither the participants nor the intervention providers will be blinded to the treatment allocation. Outcome assessors will be blinded to the treatment allocation, and the participants will be instructed not to disclose their

allocation when outcomes are assessed. The primary outcome is self-reported. Therefore, we will blind participants to previous testing scores and the trial hypothesis. A data analyst blinded to the treatment allocation will perform all pre-defined analyses on coded data. Only the PI will have the key access to the electronically stored data with information about the treatment allocation.

Patient characteristics

The following will be registered at baseline: sex, age, height, weight, duration of hip symptoms, unilateral or bilateral hip dysplasia, educational level, employment status, cohabiting status, co-morbidities, previous surgery, level of physical activity and exercise, intra-articular pain using the Flexion-adduction-Internal-rotation (FADIR) test, CE angle,[25] AI angle[26] and osteoarthritis grade evaluated with the Tönnis osteoarthritis classification.[26] A hip surgeon (SSJ) will measure the radiological characteristics using standardised standing anteroposterior radiographs. Weight, physical activity level and intra-articular pain will additionally be recorded at six-month follow-up.

Exercise and patient education (intervention)

The intervention was designed to reduce pain,[10,27] reduce physical limitations[16,28,29] and help patients cope with their pain and limitations in their everyday life.[14] In addition, it was designed as a flexible intervention requiring little time in order to motivate intervention adherence despite daily occupational and family-related responsibilities.

The intervention will follow a previously described protocol[15] and will be running over a period of six months (Table 1). The participants will be offered eight individual supervised training sessions. In these sessions, participants will be instructed in four exercises. Each of these exercises can be completed at three levels of difficulty, and all participants will start at the lowest level. The participants will be instructed to perform exercises on a perceived exertion level of 5-7 based on the Borg CR10 scale, i.e. somewhat hard (level 5), hard (level 6) or very hard (level 7),[30] and to perform a minimum of three training sessions at home each week. Additionally, participants will receive oral patient education about the mechanisms of pain in hip dysplasia,[27,31] the importance of regular physical activity and exercise,[32] the consequences of inactivity,[33] the importance of exercise adherence, the advice to lose weight if relevant and that muscle soreness is to be expected. The

intervention providers will use written treatment and exercise manuals, and the participants will be provided with paper-based exercise instructions.[15]

Table 1 Treatment delivery according to the Consensus on Exercise Reporting Template (CERT) for both groups

Topic	Item	Exercise and patient education intervention	Usual care
WHAT	1	The intervention does not require any equipment.	Usual care does not require any equipment.
WHO	2	Physical therapy students deliver the intervention under supervision by an expert team of physical therapists (UGB, KT & JSJ). Physical therapy students receive an hour of supervision per patient and four meetings with the expert team during the trial period. More details on this are provided in the supplemental material in Jacobsen et al.[15]	An experienced physical therapist delivers usual care (JSJ).
HOW	3	Exercise is provided one-to-one and delivered face-to-face.	Usual care is provided one-to-one and delivered face-to-face or by phone with video call as an option (optional to participants).
	4	Eight supervised training sessions are scheduled, including exercise instruction, correction of exercise performance, regression or progression of exercises and patient education. Sessions are scheduled as two sessions each month in the first two months and as one session each month in the last four months.	After one oral consultation, usual care is unsupervised.
	5	Adherence is documented by weekly logbook recordings and by completing the EARS at three- and six-month follow-up.	At six-month follow-up, adherence is registered by completing a standardised form on whether specific hip exercises were performed in the last six months and, if relevant, how frequent.
	6	Improvements in difficulty level of exercises, repetitions, pain or function are identified at the supervised training sessions to motivate participants to adhere to the intervention. Moreover, the rationale of exercising and the importance of regular and consistent training are given as part of the patient education.	Participants can call the usual care provider at any time for support to adhere to usual care. Moreover, rationale of physical activity, exercise and weight reduction (if relevant) will be delivered.
	7a	Participants are instructed in four exercises. Each of these exercises can be completed at three levels of difficulty (levels A, B, C; A being the highest level), and all participants start at level C. *First four weeks*: increase the number of repetitions up to 20 if the Borg CR10 scale is below three. *After four weeks*: progress to higher difficulty level of exercises and/or increase repetitions up to 20 if the Borg CR10 scale is below five. To progress to higher difficulty levels, the following criteria are mandatory: (1) an exercise is performed correct, (2) an exercise must be acceptable to participants with regard to pain and/or discomfort, (3) a minimum of 10 repetitions in three sets on the lower difficulty level can be completed.	N/A
	7b	One set on the lower (usual) difficulty level is done. If 1-3 are fulfilled, a higher level is probed. To exercise on the higher level, criteria 1-2 must be fulfilled, and the participant must be able to complete a minimum of five repetitions in sets of three on the higher difficulty level. Regression or progression is done at the supervised training sessions. At home, regression to lower difficulty level or fewer sets or repetitions are done if unacceptable pain or discomfort is experienced.	N/A
	8	Four exercises, a supine plank exercise, a side-lying plank exercise, a squat exercise and a one-leg stability exercise.[15]	One oral consultation on self-management of hip symptoms and advice on exercising and staying physically active. If relevant, advise to lose weight.

	9	Perform the four exercises at three weekly home-based training sessions	Perform regular physical activity and exercise and, if relevant, lose weight.
	10	Patient education: explain what hip dysplasia is, the rationale and importance of being physically active and exercising on a regular basis, education on tissue tolerance and pain mechanisms in hip dysplasia, knowledge about gains of specific exercise regimens and knowledge of the relation between overweight and pain.	Patient education: explain what hip dysplasia is, the rationale and importance of being physically active and exercising on a regular basis, education on tissue tolerance and pain mechanisms in hip dysplasia, gains of physically active lifestyle, and knowledge of the relation between overweight and pain.
	11	SAE and AE are registered at three- and six-month follow-up (self-reported). Any SAE or AE during supervised training sessions are registered by intervention providers. Participants are encouraged to contact the intervention providers or GP if a health problem occur. In case a medical evaluation is required, participants are referred to the Medical advisor (SSJ), who will decide if participation is safe. Exercise performance must be acceptable (i.e. pain or discomfort) to participants. If sudden joint-related pain flares beyond muscle soreness appear, exercises are regressed to fewer repetitions, sets or lower level until performance is acceptable. If one or more exercises are unacceptable regardless of regression, the exercise is not performed.	SAE and AE are registered at three- and six-month follow-up (self-reported). Participants are encouraged to contact the usual care providers or the GP if a health problem occurs. In case a medical evaluation is required, participants are referred to the medical advisor (SSJ), who decides if participation is safe.
WHERE	12	Exercises are performed unsupervised at home and at the supervised training sessions located in a fitness room at a University College in Denmark.	N/A
WHEN, HOW MUCH	13	Exercises should be performed three times a week over a period of six months. The exercises should be repeated minimum five times, be performed in sets of three and with a break of 15-30 seconds between each set.	N/A
TAILORING	14a	Exercises are tailored to each patient based upon response to the intervention through difficulty level, repetitions and acceptability. Patient education is tailored to each patient based on challanges in everyday life, experiences, confidence and self-esteem.	Advice is tailored to each patient (i.e. challenges in everyday life, experiences, confidence and self-esteem).
	14b	Exercises are individually tailored based on: (1) difficulty level (level C to A) and (2) repetitions. Moreover, (3) exercise performance has to be acceptable to participants with regard to pain and/or discomfort. Patient education is tailored based on: (1) pain and challanges, (2) pain cooping, (3) preferred physical activities or sports and (4) BMI with respect to experiences, confidence and self-esteem.	Advice is tailored based on: (1) pain and challenges, (2) pain cooping, (3) preferred physical activities or sports and (4) BMI with respect to experiences, confidence and self-esteem.
	15	The starting level of each difficulty level is: (1) correct performance, (2) performance is acceptable and (3) a minimum of five repetitions in sets of three can be completed.	N/A
HOW WELL	16a	Fidelity is registered by the intervention providers after finalisation of each patient. Fidelity describes to which extent the following categories were possible to deliver as intended: (1) Borg CR10 to determine difficulty level and repetitions, (2) patient acceptability to determine difficulty level and repetitions, (3) correct performance to determine difficulty level and repetitions, (4) patient education on rationale of regular exercise, physical activity and weight loss, if relevant.	N/A
	16b	N/A	N/A

Abbreviations: AE, adverse events; EARS, exercise adherence rating scale; GP, general practitioner; SAE, serious adverse events

Usual care (control)

Usual care will include one oral consultation provided by the PI on self-management of hip symptoms, including advice about staying physically active and exercising and, if relevant, advice to lose weight. Moreover, self-management of hip symptoms will include information about the hip morphology and advice to reduce symptoms by focusing on symptom-lowering activities and sports. The content of the information provided as usual care will be similar to the patient education provided to the participants in the intervention group. However, usual care will be limited to one session over six months and will not include instruction in specific hip exercises. In contrast, the participants in the intervention group will receive oral patient education in all supervised training sessions.

Adherence

Adherence to exercise and patient education will be self-reported and documented by weekly logbook recordings in the intervention group. At six-month follow-up, participants in the control group will be asked to report if they have performed specific hip exercises in the last month and how often and for how long (concomitant treatment). *High* adherence in the intervention group is defined as completing a minimum of 75% of scheduled training sessions (supervised and self-managed), *medium* adherence as completing 50-74%, and *low* adherence as completing less than 50%.[34] Acceptable adherence to exercise and patient education is defined as completing at least 70% of scheduled training sessions. Acceptable adherence to usual care is defined as completing less than 50% of similar training (e.g. concomitant treatment by own initiative). In addition, self-reported adherence to the intervention will be measured by the six-item Exercise Adherence Rating Scale (EARS).[35] The EARS measures non-adherence to complete adherence on a score of 0-24 points (24 highest score). Concomitant care will be registered.

Outcomes

At baseline, three-, six-, nine- and twelve-month follow-up, self-reported outcomes will be entered electronically by the participants using a survey option in REDCap (Table 2). The other outcomes will be collected at a clinical assessment at baseline and at six-month follow-up.

Primary outcome

The primary outcome will be the self-reported mean change in the pain subscale of the HAGOS from baseline to six-month follow-up (Figure 2). The HAGOS pain subscale measures the degree of hip and/or groin pain through ten questions.[36] The minimal clinically important difference (MCID) of the between-group difference of the HAGOS pain subscale is considered to be equal to the within group minimal important change of 10 points reported by Thomeé et al.[37] The pain subscale has a high responsiveness, reported as effect sizes of 1.12-1.37.[36–38] The HAGOS is a valid and reliable outcome questionnaire, which is associated with correlation coefficients of 0.2-0.7 across subitems when correlated to relevant constructs.[36,37,39] The HAGOS consists of six subscales, including pain, symptoms, activities of daily living (ADL), sport and recreation (sport/rec), participation in physical activity (PA) and hip-related quality of life (QOL).[36] The measurement error ranges from 1 to 5 points across subscales at group level in patients with hip pain.[36,37,39]

Secondary outcomes

Secondary self-reported outcomes will be the mean change in the four remaining HAGOS subscales, i.e. symptoms, ADL, sport/rec, participation and QOL,[36] and the mean change in the score of the Short Version of the International Hip Outcome Tool (iHOT-12).[40]

Table 2: Baseline characteristics and outcome measures

Measure	Baseline	3 months	6 months	9 months	12 months
Patient characteristics					
Sex, age, height	X				
Weight	X		X		
Duration of hip symptoms	X				
Unilateral/bilateral affection	X				
Educational level, employment status, family status	X				
Comorbidities	X				
Previous surgery (ankle, knee, hip, back)	X				
Physical activity and exercise	X		X		X
FADIR test	X		X		
Radiological measures					
Center-edge angle	X				
Acetabular index angle	X				
Tönnis' osteoarthritis grade	X				
Self-reported measures					
Copenhagen Hip and Groin Outcome Score (HAGOS)	X	X	X	X	X

Short Version of the International Hip Outcome Tool (iHOT-12)	X		X		X
Patient Acceptable Symptom State (PASS)			X		X
Hip/groin pain intensity in rest within the last week on a VAS for pain	X		X		X
Hip/groin pain intensity in activity within the last week on a VAS for pain	X		X		X
Back pain intensity in rest within the last week on a VAS for pain	X		X		X
Back pain intensity in activity within the last week on a VAS for pain	X		X		X
Hip and/or groin pain intensity during hip flexion, extension and abduction strength tests on the Numeric Rating Scale for pain	X		X		
Usage of analgesics (y/n/type/dose)	X		X		X
European Quality of Life – 5 Dimensions with 5 Levels (EQ-5D-5L)	X	X	X	X	X
iMTA Productivity Cost Questionnaire (iPCQ)	X	X	X	X	X
Outcome measures on physical function (most painful hip)					
Single-leg Hop for Distance Test (HDT)	X		X		
Trust in capability of the hip during the HDT on a 100 mm VAS for trust	X		X		
Y-balance test, anterior, posteromedial and posterolateral	X		X		
Isometric hip muscle strength in flexion, extension and abduction with a fixed dynamometer	X		X		
Other treatment-related outcomes					
Iliopsoas and abductor-related muscle-tendon pain	X		X		
Pain sensitisation at the forearm and hip (temporal summation of pain and pressure pain threshold)	X		X		
Concomitant care and treatments[1]	X		X		X
Adverse events and serious adverse events		X	X		
Adherence to the intervention using the six-item Exercise Adherence Rating Scale (EARS)			X		
Adherence to intervention measured as number of completed training sessions	◄	———	►		

[1]For baseline, concomitant care and treatments during the last year; for other time points, over the previous six months. Abbreviations: FADIR, Flexion-adduction-internal rotation test; iMTA, institute for Medical Technology Assessment; NRS, Numerical rating scale; VAS, Visual analogue Scale.

The iHOT-12 consists of 12 questions scored on a visual analogue scale from 0 points (worst) to 100 points (best). It is considered valid and reliable tool to measure change in young and active patients with hip disorders.[40]

Other secondary outcomes will be mean changes in performance, balance and maximal hip muscle strength (Supplementary material, performance, balance and muscle strength), which will be measured by two blinded outcome assessors in the most painful hip. The single-leg hop for distance test (HDT) is a measure of performance[41] (Supplementary Figure 1), and the Y Balance Test™ is a measure of dynamic balance[42] (Supplementary Figure 2). Maximal hip muscle strength will be measured isometrically in hip flexion, extension and abduction with a fixed dynamometer (Commander Echo MMT, JTECH Medical, Salt Lake City, UT, USA) using a standardised test protocol and external belt fixation[43,44] (Supplementary Figure 3). We will consider changes to

be clinically relevant if they are above 15 cm in HDT,[41] above 15 cm in the Y Balance Test[45] and above 0.15 Nm/kg in hip muscle strength.[44,46]

Other outcomes

Health status will be measured with the EuroQoL 5-dimension (EQ-5D-5L)[47], and productivity loss will be measured with the Productivity Costs Questionnaire (IPCQ).[48]

Acceptable symptom state will be measured with the Patient Acceptable Symptom State (PASS)[49] by the question: "Taking into account all the activities you are doing in your daily life, your level of pain, and also your functional impairments, do you consider that your current state of symptoms is acceptable (yes/no)?"

Self-reported change in back and hip and/or groin pain intensity will be measured with a 100 mm Visual Analogue Scale (VAS) for pain in rest and during activity within the last week. Change in self-reported usage of analgesics will be registered, including usage of paracetamol/acetaminophen, ibuprofen and other NSAIDs and morphine/opioids.

Change in self-reported hip and/or groin pain intensity during the hip muscle strength tests will be measured using a numerical rating scale (NRS), and trust in the capability of the hip will be measured with a 100 mm VAS for trust during the HDT.[15]

The blinded outcome assessors will assess Iliopsoas- and abductor-related muscle-tendon pain[27] and pain sensitisation. Pain sensitisation will be measured as temporal summation of pain[50] and pressure pain threshold[51] at the hip and forearm.

Adverse events

Any serious adverse event (SAE) and adverse event (AE) related to the conduct of the trial within the intervention period will be reported to the local research ethics committee. SAEs will be defined according to the International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH).[52] AEs will be defined as sudden joint-related pain flares beyond muscle soreness in the hip/groin or other parts of the body. The intervention providers and test physical therapists will report any SAE and AE during training sessions or outcome assessments. Furthermore, at three- and six-month follow-up, participants will be asked to report any

SAE or AE. In case a medical evaluation is required, participants will be referred to the hip surgeon (SSJ), who will decide if participation is safe.

Health-economic evaluation

A health-economic evaluation with 12-month follow-up will be conducted alongside the RCT to incorporate a societal perspective. The 12-month follow-up is chosen for this analysis because costs of the treatments are expected to be delayed compared to the end-point of the primary and secondary outcomes. Quality-adjusted life years (QALYs) will be the outcome in a cost-utility analysis, and the HAGOS pain will be the outcome in a cost-effectiveness analysis. QALYs will be calculated as the area under the curve using the EQ-5D-5L[47] and Danish preference weights.[53,54] Intervention and usual care costs will be calculated using micro-costing. Visits to primary health care services will be extracted from the Danish National Health Service Register for Primary Care (NHSR) and valued using the activity-based tariffs that are used for remuneration. Secondary health care services will be extracted from the National Patient Registry (NPR) and costs will be calculated using the associated diagnosis-related grouping tariff. The productivity costs per patient will be calculated using the Human Capital method and age and gender-matched average gross salaries from Statistics Denmark.

Incremental cost-effectiveness ratios (ICER) will be calculated by dividing the difference in costs by the difference in effects. The uncertainty around the ICER and 95% confidence intervals surrounding the cost differences will be estimated with 95% bootstrapped confidence intervals based on non-parametric bootstrapping (10,000 replicates)[55] and will be graphically presented on cost-effectiveness planes and cost-effectiveness acceptability curves (CEACs). These graphs will indicate if the intervention is cost-effective compared to usual care at different values of willingness to pay for a gain in outcome.

Process evaluation

A process evaluation will be conducted alongside the RCT to explore the functioning of the intervention by evaluating implementation, mechanisms of change and contextual factors.[56,57] Implementation includes the implementation process, fidelity, dose and reach (Supplementary Table 1). The implementation process will evaluate structures and resources through which delivery is achieved. Fidelity aspects will evaluate the extent to deliver each component as planned and registered during the intervention period using self-report

questionnaires. Dose will evaluate how much intervention is delivered and registered during the intervention period using routine monitoring forms, and reach will be evaluated as patterns in uptake and adherence by baseline patient characteristics registered before and during the intervention period. Mechanisms of change include interactions between the intervention, the intervention providers and the participants. Interactions will be evaluated through focus group interviews and by quantitative data on reasons for not receiving surgery. Contextual factors will include events, personal understandings and interactions and their possible influence on the implementation. Contextual factors will be evaluated through one-to-one semi-structured interviews during and after the intervention period. Findings from quantitative and quantitative analyses will be merged, interpreted and reported jointly. The results from the process evaluation will be used to refine the programme theory, including a logic model to be used in a potential full-scale implementation of the intervention (Supplementary Figure 4).

Long-term follow-up

Participants will be invited to complete the HAGOS and iHOT-12 after 2, 5 and 10 years to investigate predictors of long-term outcome and progression to hip-preserving surgery or hip replacement. In addition, we plan to evaluate if hip osteoarthritis progresses over 5 and 10 years by assessing the degree of osteoarthritis with the Tönnis osteoarthritis classification.[26]

Data management

Once a participant is enrolled, efforts will be made to collect all outcomes despite deviations from the intervention or usual care. All participants will receive a text-message reminder for the six-month follow-up assessment. If a patient is not able to attend or cancels the appointment, the patient will be offered to reschedule. If a patient does not attend the six-month follow-up assessment, the patient will be asked to complete the self-reported outcomes. Moreover, if a patient does not complete self-reported outcomes at any follow-up, one reminder will be sent. Reasons for dropping out and non-adherence to planned training sessions will be registered. All data collected in this trial is directly entered into REDCap for safe storage and will be treated confidentially by the research staff. The PI will perform checks of protocol adherence and data completeness. No

formal data monitoring committee will be established. The authors will discuss any SAE yearly, classify these into subcategories and monitor recruitment, treatment and retention. No interim analysis will be performed.

Sample size

The power calculation was based on a clinical superiority calculation.[58] The expected mean difference between groups was 15 points in the change in HAGOS pain over a six-month follow-up period.[15] The superiority margin was a minimal clinically important difference (MCID) of 10 points in the between-group change in the HAGOS pain over six months,[37] representing the lower end of the 95% confidence interval of the expected mean difference between groups. Given these assumptions, a sample size of 200 participants (n=100 in each group), a common standard deviation of 13 HAGOS pain points[15] for the change in each group and an alpha level of 5%, we will reach a power of 86%. Based on an expected dropout of 15% during the six-month follow-up period,[15] our sample size will be 170 participants (85 in each group), and the power of the trial will be 80%.

Statistical analysis

All primary and secondary outcomes will be analysed with the intention-to-treat principle. Between-group differences from baseline to three and six-month follow-up of continuous outcomes will be estimated using repeated measurement analysis in a mixed-effects model, including participant as random effect, with a fixed factor for group and time and the corresponding interaction (group x time), adjusted for baseline values. Between-group differences of continuous outcomes from baseline to six-month follow-up will be analysed with an unpaired t-test, where between-group differences of categorical data from baseline to six-month follow-up will be analysed with a binominal regression model using risk difference as a measure of association. All results will be presented with 95% confidence intervals and associated p values. A two-sided $p<0.05$ will be considered as statistically significant. A pre-specified statistical analysis plan will be made publicly available prior to inclusion of the final patient. The statistical analyses and the data interpretation will be blinded to group allocation. Data analysis will be performed with Stata 16) software package (StataCorp, College Station, TX, USA).

Ethics and dissemination

The trial will be conducted and reported in accordance with the WMA declaration of Helsinki, and the data will be handled in accordance with the General Data Protection Regulation. This trial has been approved by the Committee on Health Research Ethics in the Central Denmark Region (project ID: 1-10-72-336-20). The Danish Data Protection Agency authorised patient data handling (project ID: 1-16-02-678-20), and the study protocol has been registered at ClinicalTrials (trial identifier: NCT04795843). Any protocol amendments will be registered at ClinicalTrials, reported to the Committee on Health Research Ethics in the Central Denmark Region and addressed in the primary trial paper. Results will be published in international peer-reviewed scientific journals with open access. Authorship will adhere to the Vancouver conventions as outlined by the International Committee of Medical Journal Editors.[59]

Explorative analyses

By using subgroup stratification, we will explore if muscle-tendon pain[27] and pain sensitisation modify between-group changes of the primary and secondary outcomes over six months. Furthermore, we plan to conduct an instrumental variable analysis on primary and secondary outcomes in an attempt to investigate the efficacy of the intervention.[60] These analyses will be reported in secondary papers with clear reference to the primary trial paper.

Patient and public involvement

A qualitative study of 17 patients[14] and a feasibility study of 30 patients[15] collected information on expectations, needs and opinions about content, frequency and outcome of treatment as well as burden to participate. This information has been used to refine the intervention and the study procedures.

DISCUSSION

The majority of patients with hip dysplasia are treated non-surgically in primary care, and some data exists on changes after surgical treatment.[1,16,27,61–63] Nevertheless, there is limited evidence on what constitutes effective primary care for patients with hip dysplasia. By highlighting the benefits, harms, costs and processes of exercise and patient education, the MovetheHip trial will provide valuable evidence for patients, health professionals and decision-makers.

Strengths and limitations

The strengths of this trial are the preceding feasibility study[15] and the parallel health-economic and process-evaluation studies. Another strength is the development of a well-described flexible intervention designed to require little time to fit into the daily life of young to middle-aged patients, as this holds a potential for large-scale implementation.[14] Additional strengths are the use of assessor blinding and the randomised controlled design with blinded intention-to-treat analyses.

A limitation is that intervention providers and patients are not blinded to treatment allocation. However, blinded assessors will assess all clinical outcomes, and a blinded data analyst will perform all pre-defined analyses. Moreover, the participants will be blinded to the trial hypotheses, and both participants and assessors will be blinded to previous testing scores at all follow-ups. Another limitation is the heterogeneity of the participants, which might make it difficult to show between-group differences. Finally, participants may choose various concomitant care, which may add to changes in outcomes. However, any concomitant care or treatment will be registered and reported as part of the health-economic evaluation.

AUTHORS' CONTRIBUTIONS

JSJ is the PI. IM, KT and JSJ designed the preliminary version of the present trial. RON contributed with methodological and statistical aspects, whereas DS and LGO provided input to the design of the intervention and to the design of the process evaluation study. LGO and MT contributed to the design of the health-economic evaluation. SSJ and CF provided imported insights on the clinical implication of the trial and recruited participants. All authors contributed to the drafting of this manuscript and approved the final version.

ACKNOWLEDGEMENTS

We would like to thank physical therapists Gitte Hjørnholm Madsen and Lene Boetker Nielsen from the Department of Physiotherapy and Occupational Therapy at Aarhus University Hospital, who were responsible for the baseline and six-month follow-up assessments. Furthermore, we would like to thank the intervention providers, Sofie Kristensen and Mikkel Gade, for delivering the exercise and patient education intervention, and the study coordinator, Ulla Gasseholm Baek, for supervising the intervention providers. Lastly, we would like to thank the Clinical Trials Unit from the Department of Clinical Medicine, Aarhus University, for data management support and access to REDCap.

FUNDING

This work was supported by the Danish foundation TrygFonden (grant number: 150195), the Danish Health Fund (grant number: 19-B-0170), the Danish Rheumatism Association (grant number: R175-A6011), Aase and Ejnar Danielsen's Foundation (N/A), the Research Foundation of the Association of Danish Physiotherapists (NA), the Fogh-Nielsen Legacy, Aarhus University (N/A), and the A.P. Moller Foundation (grant number: 20-L-0096).

COMPETING INTERESTS

None declared

PATIENT CONSENT FOR PUBLICATION

The person pictured in the supplementary Material has given consent for publication

ORCID IDS

Julie S Jacobsen: 0000-0002-3323-3631

Kristian Thorborg: 0000-0001-9102-4515

Rasmus Oestergaard Nielsen: 0000-0001-5757-1806

Stig Storgaard Jakobsen: 0000-0002-1890-3617

Casper Foldager: 0000-0001-8729-0810

Dorthe Sørensen: 0000-0001-6362-3385

Lisa Gregersen Oestergaard: 0000-0003-2255-1391

Maurits van Tulder: 0000-0002-7589-8471

Inger Mechlenburg: 0000-0001-5432-8691

REFERENCES

1 Mechlenburg I, Nyengaard JR, Rømer L, *et al.* Changes in load-bearing area after Ganz periacetabular osteotomy evaluated by multislice CT scanning and stereology. *Acta Orthop Scand* 2004;**75**:147–53. doi:10.1080/00016470412331294395

2 Gosvig KK, Jacobsen S, Sonne-Holm S, *et al.* Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: A population-based survey. *Journal of Bone and Joint Surgery - Series A* 2010;**92**:1162–9. doi:10.2106/JBJS.H.01674

3 Engesæter IØ, Laborie LB, Lehmann TG, *et al.* Prevalence of radiographic findings associated with hip dysplasia in a population-based cohort of 2081 19-year-old Norwegians. *Bone Joint J* 2013;**95-B**:279–85. doi:10.1302/0301-620X.95B2.30744

4 Birrell F. Syndrome of symptomatic adult acetabular dysplasia (SAAD syndrome). *Ann Rheum Dis* 2003;**62**:356–8. doi:10.1136/ard.62.4.356

5 Pun S. Hip dysplasia in the young adult caused by residual childhood and adolescent-onset dysplasia. *Curr Rev Musculoskelet Med* 2016;**9**:427–34. doi:10.1007/s12178-016-9369-0

6 Murphy SB, Ganz R, Müller ME. The prognosis in untreated dysplasia of the hip. A study of radiographic factors that predict the outcome. *J Bone Joint Surg Am* 1995;**77**:985–9.

7 Clohisy JC, Dobson MA, Robison JF, *et al.* Radiographic structural abnormalities associated with premature, natural hip-joint failure. *Journal of Bone and Joint Surgery - Series A* 2011;**93**:3–9. doi:10.2106/JBJS.J.01734

8 Agricola R, Heijboer MP, Roze RH, *et al.* Pincer deformity does not lead to osteoarthritis of the hip whereas acetabular dysplasia does: Acetabular coverage and development of osteoarthritis in a nationwide prospective cohort study (CHECK). *Osteoarthritis and Cartilage* 2013;**21**:1514–21. doi:10.1016/j.joca.2013.07.004

9 Wyles CC, Heidenreich MJ, Jeng J, *et al.* The John Charnley Award: Redefining the Natural History of Osteoarthritis in Patients With Hip Dysplasia and Impingement. *Clin Orthop Relat Res* 2017;**475**:336–50. doi:10.1007/s11999-016-4815-2

10 Clohisy JC, Ackerman J, Baca G, *et al.* Patient-reported outcomes of periacetabular osteotomy from the prospective ANCHOR cohort study. Journal of Bone and Joint Surgery - American Volume. 2017;**99**:33–41. doi:10.2106/JBJS.15.00798

11 Jashi R El, Gustafson MB, Jakobsen MB, *et al.* The association between gender and familial prevalence of hip dysplasia in danish patients. *HIP International* 2017;**27**:299–304. doi:10.5301/hipint.5000461

12 Jacobsen JS, Søballe K, Thorborg K, *et al.* Patient-reported outcome and muscle–tendon pain after periacetabular osteotomy are related: 1-year follow-up in 82 patients with hip dysplasia. *Acta Orthopaedica* 2019;**90**:40–5. doi:10.1080/17453674.2018.1555637

13 Boje J, Caspersen CK, Jakobsen SS, *et al.* Are changes in pain associated with changes in quality of life and hip function 2 years after periacetabular osteotomy? A follow-up study of 321 patients. *Journal of Hip Preservation Surgery* 2019;**6**:69–76. doi:10.1093/jhps/hnz009

14 Jorgensen MD, Frederiksen SB, Sørensen D, *et al.* Experiences of living with developmental dysplasia of the hip in adults not eligible for surgical treatment: a qualitative study. *BMJ Open* 2021;**11**:e052486. doi:10.1136/BMJOPEN-2021-052486

15 Jacobsen JS, Thorborg K, Sørensen D, *et al.* Feasibility and acceptability of a six-month exercise and patient education intervention for patients with hip dysplasia: A mixed methods study. *Musculoskelet Sci Pract* 2022;**61:102615**. doi:10.1016/j.msksp.2022.102615

16 Jacobsen JS, Jakobsen SS, Søballe K, *et al.* Isometric hip strength impairments in patients with hip dysplasia are improved but not normalized 1 year after periacetabular osteotomy: a cohort study of 82 patients. *Acta Orthop* 2021;**92**:285–91. doi:10.1080/17453674.2020.1864911

17 Kuroda D, Maeyama A, Naito M, *et al.* Dynamic hip stability, strength and pain before and after hip abductor strengthening exercises for patients with dysplastic hips. *Isokinetics and Exercise Science* 2013;**21**:95–100. doi:10.3233/IES-130480

18 Gambling T, Long AF. An exploratory study of young women adjusting to developmental dysplasia of the hip and deciding on treatment choices. *Chronic Illness* 2012;**8**:17–30. doi:10.1177/1742395311417638

19 Troelsen A, Elmengaard B, Søballe K. A new minimally invasive transsartorial approach for periacetabular osteotomy. *J Bone Joint Surg Am* 2008;**90**:493–8. doi:10.2106/JBJS.F.01399

20 Coobs BR, Xiong A, Clohisy JC. Contemporary Concepts in the Young Adult Hip Patient: Periacetabular Osteotomy for Hip Dysplasia. *Journal of Arthroplasty* 2015;**30**:1105–8. doi:10.1016/j.arth.2015.02.045

21 Novais EN, Potter GD, Clohisy JC, *et al.* Obesity is a major risk factor for the development of complications after peri-acetabular osteotomy. *The Bone & Joint Journal* 2015;**97-B**:29–34. doi:10.1302/0301-620X.97B1.34014

22 Jakobsen SS, Overgaard S, Søballe K, *et al.* The interface between periacetabular osteotomy, hip arthroscopy and total hip arthroplasty in the young adult hip. *EFORT Open Reviews* 2018;**3**:408–17. doi:10.1302/2058-5241.3.170042

23 Chan AW, Tetzlaff JM, Altman DG, *et al.* SPIRIT 2013 Statement: defining standard protocol items for clinical trials. *Revista panamericana de salud publica = Pan American journal of public health* 2015;**38**:506–14. doi:10.7326/0003-4819-158-3-201302050-00583

24 Slade SC, Dionne CE, Underwood M, *et al.* Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *Br J Sports Med* 2016;**50**:1428–37. doi:10.1136/BJSPORTS-2016-096651

25 Wiberg G. Studies on Dysplastic Acetabula and Congenital Subluxation of the Hip Joint with Special References to the Complication of Osteoarthritis. *Acta Chirurgica Scand Suppl* 1939;**58**:1–132.

26 Tönnis D. *Congenital dysplasia and dislocation of the hip in children and adults*. Berlin Heidelberg, New York: : Springer 1987.

27 Jacobsen JS, Hölmich P, Thorborg K, *et al.* Muscle-tendon-related pain in 100 patients with hip dysplasia: prevalence and associations with self-reported hip disability and muscle strength. *Journal of Hip Preservation Surgery* 2018;**5**:39–46. doi:10.1093/jhps/hnx041

28 Jacobsen JS, Nielsen DB, Sørensen H, *et al.* Changes in walking and running in patients with hip dysplasia. *Acta Orthop* 2013;**84**:265–70. doi:10.3109/17453674.2013.792030

29 Mortensen L, Schultz J, Elsner A, *et al.* Progressive resistance training in patients with hip dysplasia: A feasibility study. *Journal of Rehabilitation Medicine* 2018;**50**:751–8. doi:10.2340/16501977-2371

30 Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982;**14**:377–81.

31 Hartig-Andreasen C, Soballe K, Troelsen A. The role of the acetabular labrum in hip dysplasia. *Acta Orthopaedica* 2013;**84**:60–4. doi:10.3109/17453674.2013.765626

32 Rausch Osthoff AK, Niedermann K, Braun J, *et al.* 2018 EULAR recommendations for physical activity in people with inflammatory arthritis and osteoarthritis. *Ann Rheum Dis* 2018;**77**:1251–60. doi:10.1136/ANNRHEUMDIS-2018-213585

33 Li J, Siegrist J. Physical activity and risk of cardiovascular disease--a meta-analysis of prospective cohort studies. *Int J Environ Res Public Health* 2012;**9**:391–407. doi:10.3390/IJERPH9020391

34 Skou ST, Roos EM, Laursen MB, *et al.* Total knee replacement plus physical and medical therapy or treatment with physical and medical therapy alone: A randomised controlled trial in patients with knee osteoarthritis (the MEDIC-study). *BMC Musculoskeletal Disorders* 2012;**13**. doi:10.1186/1471-2474-13-67

35 Newman-Beinart NA, Norton S, Dowling D, *et al.* The development and initial psychometric evaluation of a measure assessing adherence to prescribed exercise: the Exercise Adherence Rating Scale (EARS). *Physiotherapy* 2017;**103**:180–5. doi:10.1016/j.physio.2016.11.001

36 Thorborg K, Hölmich P, Christensen R, *et al.* The Copenhagen Hip and Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. *Br J Sports Med* 2011;**45**:478–91. doi:10.1136/bjsm.2010.080937

37 Thomeé R, Jónasson P, Thorborg K, *et al.* Cross-cultural adaptation to Swedish and validation of the Copenhagen Hip and Groin Outcome Score (HAGOS) for pain, symptoms and physical function in patients with hip and groin disability due to femoro-acetabular impingement. *Knee Surgery, Sports Traumatology, Arthroscopy* 2014;**22**:835–42. doi:10.1007/s00167-013-2721-7

38 Stone A V, Jacobs CA, Luo TD, *et al.* High Degree of Variability in Reporting of Clinical and Patient-Reported Outcomes After Hip Arthroscopy. *American Journal of Sports Medicine* 2018;**46**:3040–6. doi:10.1177/0363546517724743

39 Kemp JL, Collins NJ, Roos EM, *et al.* Psychometric Properties of Patient-Reported Outcome Measures for Hip Arthroscopic Surgery. *The American Journal of Sports Medicine* 2013;**41**:2065–73. doi:10.1177/0363546513494173

40 Griffin DR, Parsons N, Mohtadi NGH, *et al.* A short version of the International Hip Outcome Tool (iHOT-12) for use in routine clinical practice. *Arthroscopy - Journal of Arthroscopic and Related Surgery* 2012;**28**:611–8. doi:10.1016/j.arthro.2012.02.027

41 Kemp JL, Schache AG, Makdissi M, *et al.* Greater understanding of normal hip physical function may guide clinicians in providing targeted rehabilitation programmes. *J Sci Med Sport* 2013;**16**. doi:10.1016/j.jsams.2012.11.887

42 Plisky PJ, Gorman PP, Butler RJ, *et al.* The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther* 2009;**4**:92–9.

43 Thorborg K, Petersen J, Magnusson SP, *et al.* Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scandinavian Journal of Medicine & Science in Sports* 2010;**20**:493–501. doi:10.1111/j.1600-0838.2009.00958.x

44 Thorborg K, Bandholm T, Hölmich P. Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surgery, Sports Traumatology, Arthroscopy* 2013;**21**:550–5. doi:10.1007/s00167-012-2115-2

45 Linek P, Sikora D, Wolny T, *et al.* Reliability and number of trials of Y Balance Test in adolescent athletes. *Musculoskelet Sci Pract* 2017;**31**:72–5. doi:10.1016/j.msksp.2017.03.011

46 Krantz MM, Åström M, Drake AM. STRENGTH AND FATIGUE MEASUREMENTS OF THE HIP FLEXOR AND HIP EXTENSOR MUSCLES: TEST-RETEST RELIABILITY AND LIMB DOMINANCE EFFECT. *International Journal of Sports Physical Therapy* 2020;**15**:967–76. doi:10.26603/ijspt20200967

47 Szende A, Janssen B, Cabasés J. *Self-reported population health: An international perspective based on EQ-5D*. Dordrecht Heidelberg New York London: : SpringerOpen 2014. doi:10.1111/1744-7941.12100

48 Bouwmans C, Krol M, Severens H, *et al.* The iMTA Productivity Cost Questionnaire. *Value in Health* 2015;**18**:753–8. doi:10.1016/j.jval.2015.05.009

49 Kvien TK, Heiberg T, Hagen KB. Minimal clinically important improvement/difference (MCII/MCID) and patient acceptable symptom state (PASS): What do these concepts mean? In: *Annals of the Rheumatic Diseases*. 2007. doi:10.1136/ard.2007.079798

50 O'Leary H, Smart KM, Moloney NA, *et al.* Pain sensitization associated with nonresponse after physiotherapy in people with knee osteoarthritis. *Pain* 2018;**159**:1877–86. doi:10.1097/j.pain.0000000000001288

51 Willett MJ, Siebertz M, Petzke F, *et al.* The Extent of Pain Is Associated With Signs of Central Sensitization in Patients With Hip Osteoarthritis. *Pain Practice* 2020;**20**:277–88. doi:10.1111/papr.12851

52 INTERNATIONAL COUNCIL FOR HARMONISATION OF TECHNICAL REQUIREMENTS FOR PHARMACEUTICALS FOR HUMAN USE (ICH). ICH HARMONISED GUIDELINE INTEGRATED ADDENDUM TO ICH E6(R1): GUIDELINE FOR GOOD CLINICAL PRACTICE E6(R2). 2016. Https://database.ich.org/sites/default/files/E6_R2_Addendum.pdf (accessed 8 Dec 2021).

53 Wittrup-Jensen KU, Lauridsen J, Gudex C, *et al.* Generation of a Danish TTO value set for EQ-5D health states. *Scand J Public Health* 2009;**37**:459–66. doi:10.1177/1403494809105287

54 Drummond MF, Sculpher MJ, Torrance GW, *et al. Methods for the economic evaluation of health care programmes*. Third edit. Oxford University Press 2005.

55 Johnson RW. An Introduction to the Bootstrap. *Teaching Statistics* 2001;**23**:49–54. doi:10.1111/1467-9639.00050

56 Moore GF, Audrey S, Barker M, *et al.* Process evaluation of complex interventions: Medical Research Council guidance. *BMJ (Online)* 2015;**350**. doi:10.1136/bmj.h1258

57 Skivington K, Matthews L, Simpson SA, *et al.* A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ* 2021;**374**. doi:10.1136/BMJ.N2061

58 Chow S-C, Wang H, Shao J. *Sample Size Calculations in Clinical Research*. 2nd Editio. New York 2007: Chapman and Hall/CRC 2007. doi:10.1201/9781584889830

59 International Committee of Medical Journal Editors. Defining the Role of Authors and Contributors. Http://www.icmje.org/recommendations/browse/roles-and-responsibilities/defining-the-role-of-authors-and-contributors.html (Accessed 28 03 2022).

60 Greenland S. An introduction to instrumental variables for epidemiologists. *International Journal of Epidemiology* 2000;**29**:722–9. doi:10.1093/ije/29.4.722

61 Fujita J, Doi N, Kinoshita K, *et al.* Rate of Return to Work After Periacetabular Osteotomy and Its Influencing Factors. *J Bone Joint Surg Am* 2022;**104**:732. doi:10.2106/JBJS.21.00548

62 Lerch TD, Steppacher SD, Liechti EF, *et al.* One-third of Hips After Periacetabular Osteotomy Survive 30 Years With Good Clinical Results, No Progression of Arthritis, or Conversion to THA. *Clinical Orthopaedics and Related Research®* 2017;**475**:1154–68. doi:10.1007/s11999-016-5169-5

63 Hartig-Andreasen C, Troelsen A, Thillemann TM, *et al.* What factors predict failure 4 to 12 years after periacetabular osteotomy? *Clinical Orthopaedics and Related Research* 2012;**470**:2978–87. doi:10.1007/s11999-012-2386-4

Legend: Abbreviations: PAO, periacetabular osteotomy; HAGOS, Copenhagen Hip and Groin Outcome Score; BMI, Body mass index.

Caption: **Figure 1** Flow of participants through the trial.

Legend: The mean score of the intervention group (exercise and patient education) is anticipated to change from 60 to 80 points, corresponding to an improvement of 20 points over six months. In contrast, the mean score of the control group (usual care) is anticipated to change from 60 to 65 points, corresponding to an improvement of 5 points over six months. These group-based improvements lead to a hypothesised between-group change difference of 15 points (95% CI 10-20). The lower limit of the 95% CI between-group change difference of 10 points represents the minimal clinically important difference (MCIC), which is described in our hypothesis and included in our power calculation.

Caption: **Figure 2** Illustration of anticipated changes in the Copenhagen Hip and Groin Outcome Score (HAGOS) over a six-month follow-up period. Values are mean (95% CIs).

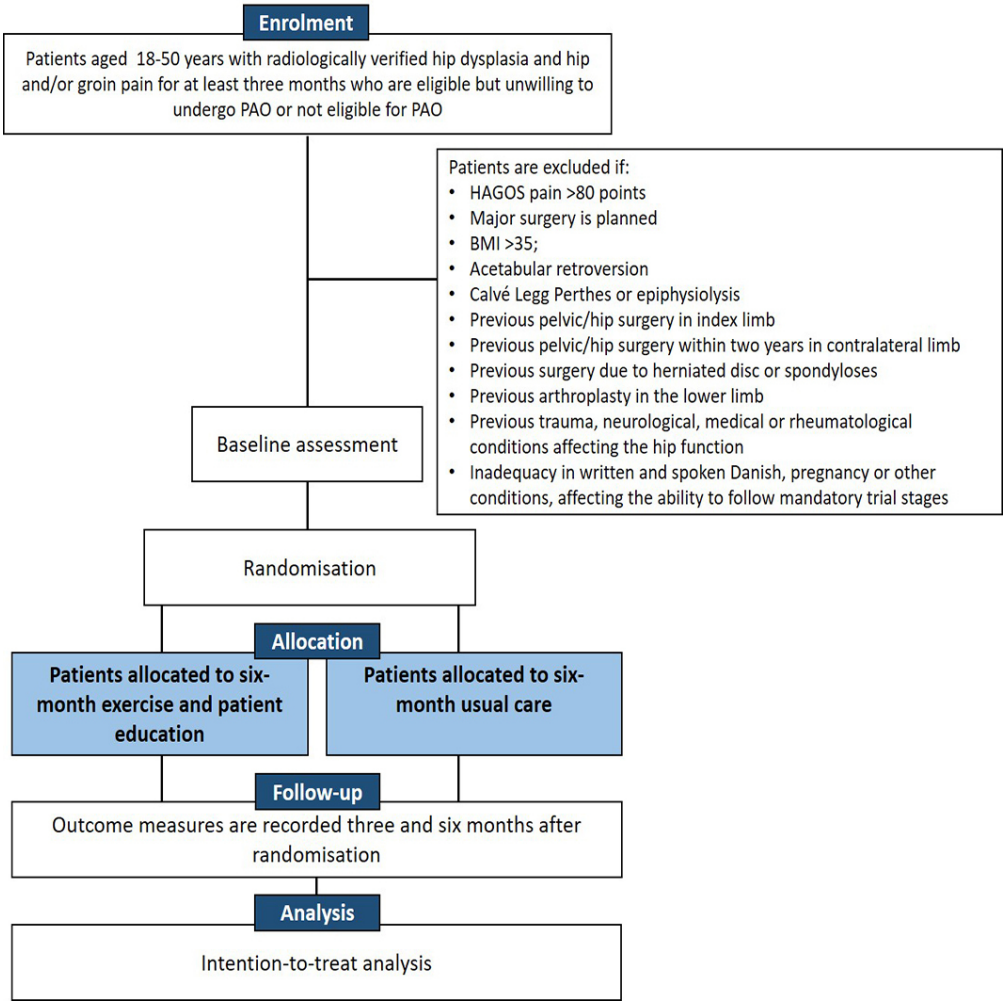


Figure 1 Flow of participants through the trial. Abbreviations: PAO, periacetabular osteotomy; HAGOS, Copenhagen Hip and Groin Outcome Score; BMI, Body mass index.

90x90mm (300 x 300 DPI)

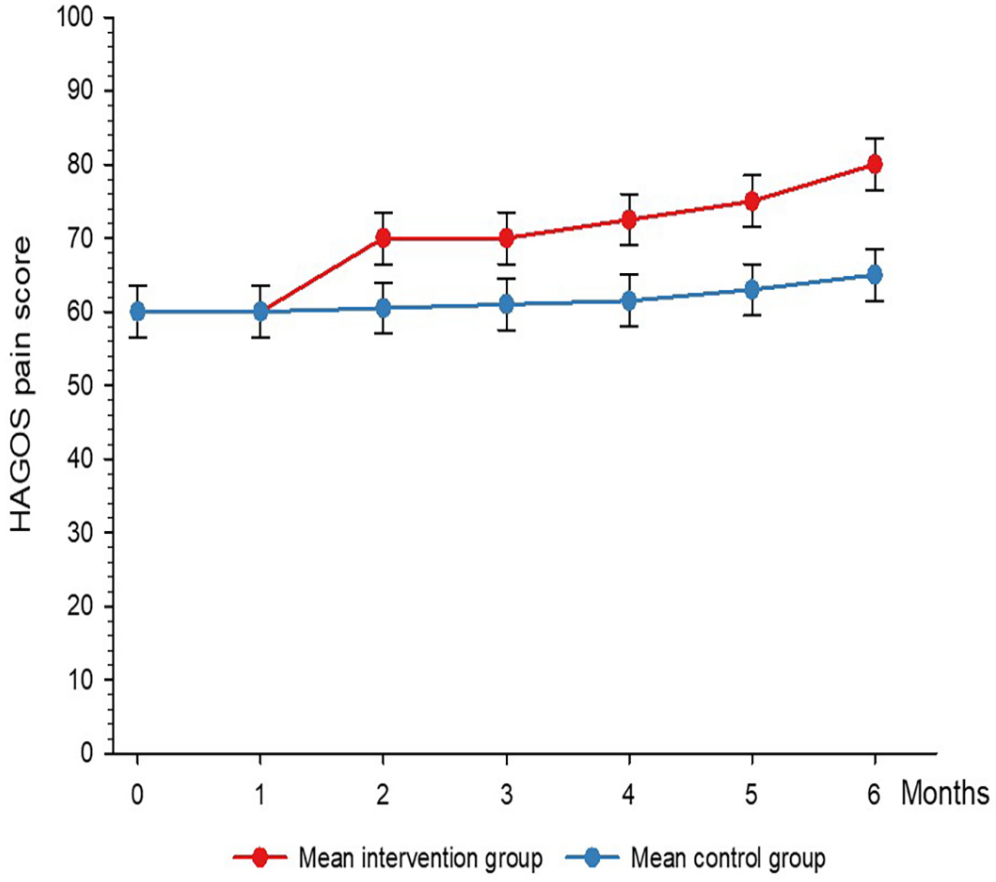
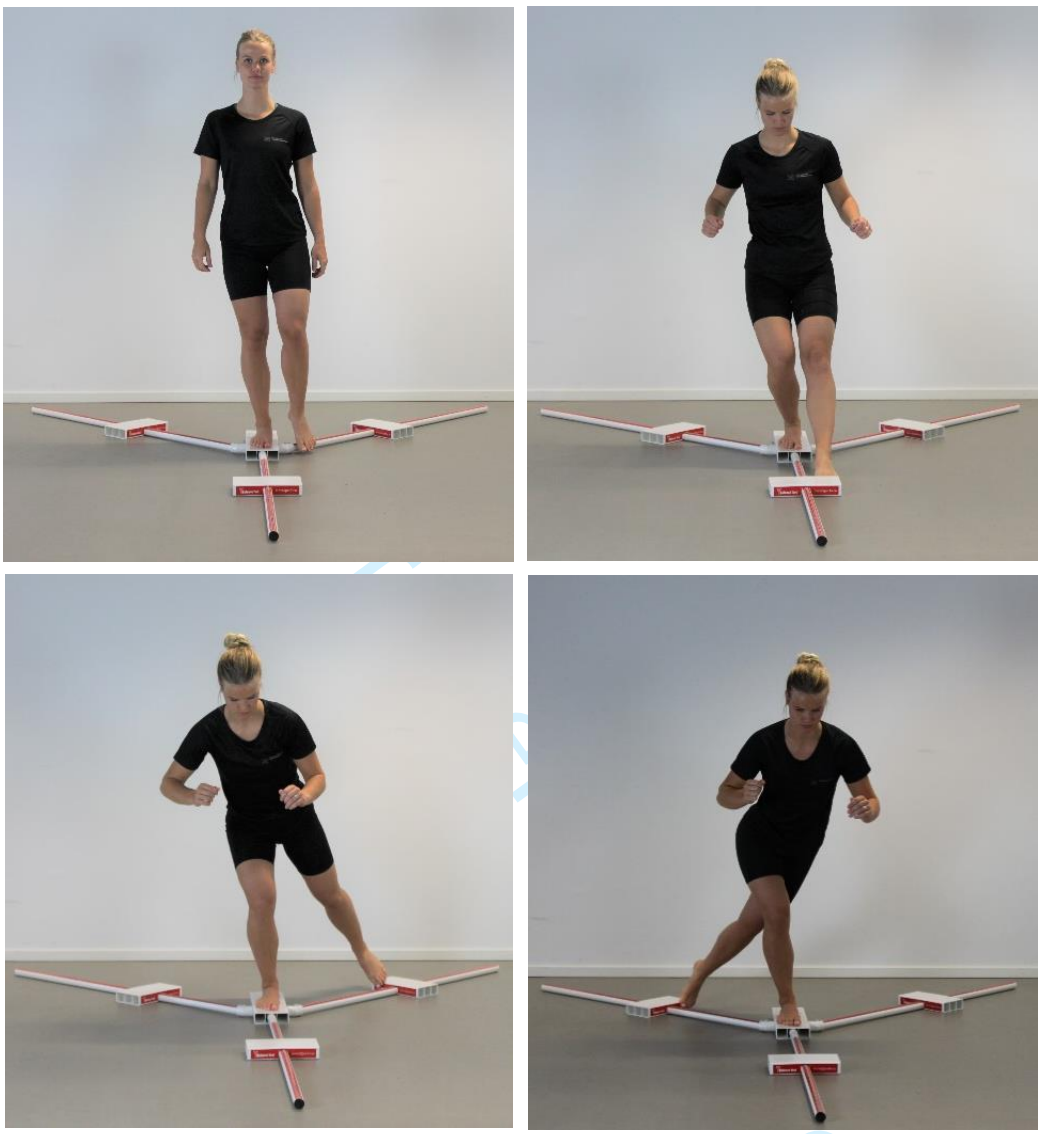


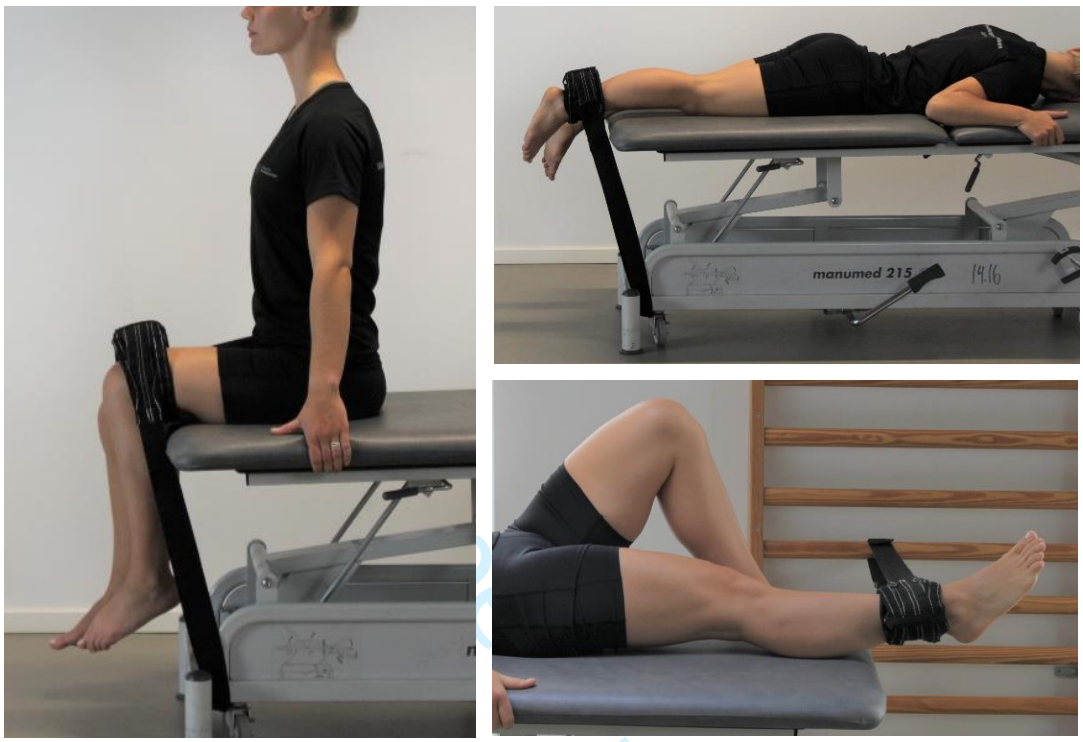
Figure 2 Illustration of anticipated changes in the Copenhagen Hip and Groin Outcome Score (HAGOS) over a six-month follow-up period. Values are mean (95% CIs). The mean score of the intervention group (exercise and patient education) is anticipated to change from 60 to 80 points, corresponding to an improvement of 20 points over six months. In contrast, the mean score of the control group (usual care) is anticipated to change from 60 to 65 points, corresponding to an improvement of 5 points over six months. These group-based improvements lead to a hypothesised between-group change difference of 15 points (95% CI 10-20). The lower limit of the 95% CI between-group change difference of 10 points represents the minimal clinically important difference (MCIC), which is described in our hypothesis and included in our power calculation.

90x90mm (300 x 300 DPI)

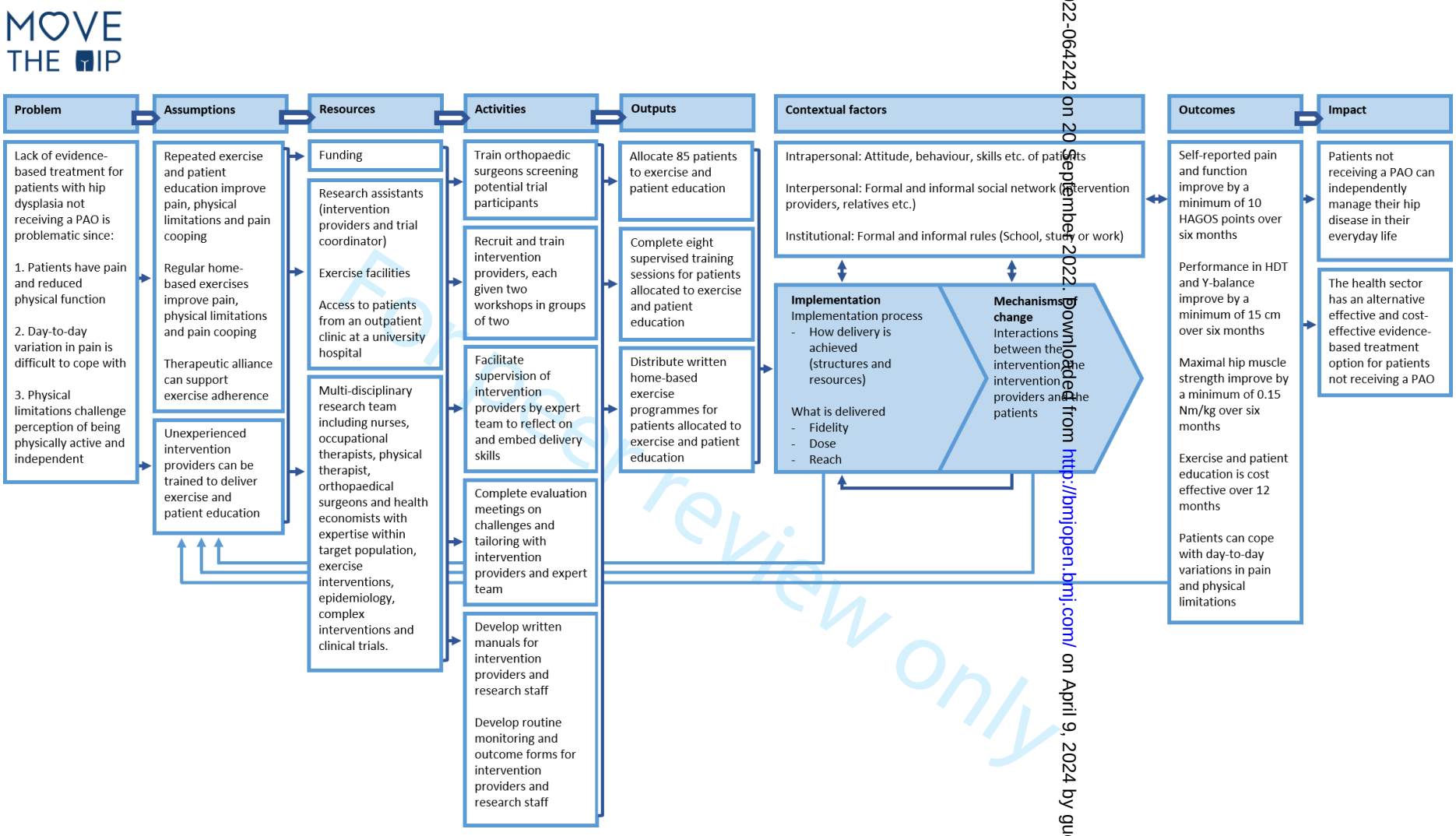
Supplementary Figure 1 Single-leg hop for distance test with both arms behind back.



Supplementary Figure 2 Y Balance test™. The figure illustrates the starting position (top left corner), the anterior, posteromedial and posterolateral reach (bottom right corner).



Supplementary Figure 3 Isometric hip muscle strength. The figure illustrates the testing procedure in flexion (left), extension (top right corner) and abduction (lower right corner) with external belt fixation



Supplementary Figure 4 Logic model for exercise and patient education in MovetheHip trial. Abbreviations: HAGOS, Copenhagen Hip and Groin Outcome Score; HDT, single-leg hop for distance test; PAO, periacetabular osteotomy.

MOVE THE HIP

THE HOP FOR DISTANCE TEST

Standing barefoot behind a starting line, the participants are asked to hop as far as possible on the leg of the most painful hip and to land on the same foot, with both arms behind the back [2] (Supplementary Figure 1). The length of the best out of three attempts is measured from the starting line to the posterior aspect of the heel of the landing foot. The hop distance is measured in centimetres with inflexible measuring tape and normalised to height [1]. An attempt is discarded and repeated if balance cannot be maintained for 2-3 seconds after landing. If the participant improves more than 10 centimetres between the second and third hop, additional hops are performed until an increase of less than 10 centimetres is measured. Prior to the test, the outcome assessors will demonstrate how the test should be performed, and the participants are given two practice tests. The intra-rater reliability has been reported as excellent (standard error of measurement (SEM) is 3 centimetres, and the intra-class correlation coefficient (ICC) is 0.98) [1].

THE Y BALANCE TEST™

The Y balance test kit™ (PhysioSupplies, Groningen, Netherlands) is used (Supplementary Figure 2), and a reliable test protocol will be followed [3]. While maintaining single leg stance on the leg of the most painful hip, the participants are instructed to stand on the leg in the centre of the platform behind the red line. The participants are instructed to reach with the free limb in the anterior direction for three attempts, followed by three attempts in the posteromedial direction and then three trials in posterolateral direction, all named in relation to the stance foot. The participants are instructed to push the distance indicator as far as possible in each direction and return to the starting position (single leg stance). The entire surface of the foot must remain in contact with the platform throughout the entire duration of the movement. The maximal reach distance of the three attempts for each reach is measured down to half a centimetre. The maximal reach distance is normalised to limb length by dividing reach distance with limp length (anterior superior iliac spine to the most distal portion of the medial malleolus). The greatest reach distances for each of the directions are summed to yield a composite reach distance. An attempt will be discarded and repeated if: 1) the unilateral stance fails, 2) contact with the reach indicator fails, 3) the reach indicator is used for stance support, 4) the reach foot is not returned to the starting position under control or 5) the heel on the platform is lifted. Prior to the test, each participant will be given six practice tests in each direction. The intra-rater reliability has been reported as excellent (standard error of measurement (SEM) is 2-3 centimetres, and the intra-class correlation coefficient (ICC) is 0.85-0.98) [3].

MOVE THE HIP

ISOMETRIC HIP MUSCLE STRENGTH TEST

Hip muscle strength is measured isometrically with a dynamometer (Commander Echo MMT, JTECH Medical, Salt Lake City, UT, USA) in the most painful hip using an external belt fixation [5] (Supplementary Figure 3). A reliable test protocol will be followed [4]. Hip muscle strength is measured with a make test in hip flexion, extension and abduction (in a random order). The test positions are sitting for hip flexion, prone for hip extension and supine for hip abduction. The participants are instructed to exert a five-second maximum voluntary contraction against the dynamometer. The best out of four attempts in each direction will be registered together with torque as Nm/kg by multiplying with limb length and dividing by body weight. In hip extension and abduction, limb length is measured from the anterior superior iliac spine to five centimetres proximal to the lateral malleolus. In hip flexion, limb length is measured from the anterior superior iliac spine to five centimetres proximal to the basis of patella. Prior to tests, participants will be given two practice submaximal contractions; one into the tester´s hand and another against the dynamometer. The inter-rater reliability has been reported as good (standard error of measurement (SEM) is 0.12-0.25Nm/kg, and the intra-class correlation coefficient (ICC) is 0.72-0.92) [6].

MOVE THE HIP

REFERENCES

1 Kemp JL, Schache AG, Makdissi M, *et al.* Greater understanding of normal hip physical function may guide clinicians in providing targeted rehabilitation programmes. *J Sci Med Sport* 2013;**16**. doi:10.1016/j.jsams.2012.11.887

2 Ageberg E, Cronström A. Agreement between test procedures for the single-leg hop for distance and the single-leg mini squat as measures of lower extremity function. *BMC Sports Sci Med Rehabil* 2018;**10**:15. doi:10.1186/s13102-018-0104-6

3 Plisky PJ, Gorman PP, Butler RJ, *et al.* The reliability of an instrumented device for measuring components of the star excursion balance test. *N Am J Sports Phys Ther* 2009;**4**:92–9.

4 Thorborg K, Petersen J, Magnusson SP, *et al.* Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scand J Med Sci Sports* 2010;**20**:493–501. doi:10.1111/j.1600-0838.2009.00958.x

5 Thorborg K, Bandholm T, Hölmich P. Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surgery, Sport Traumatol Arthrosc* 2013;**21**:550–5. doi:10.1007/s00167-012-2115-2

6 Jacobsen JS, Hölmich P, Thorborg K, *et al.* Muscle-tendon-related pain in 100 patients with hip dysplasia: prevalence and associations with self-reported hip disability and muscle strength. *J Hip Preserv Surg* 2018;**5**:39–46. doi:10.1093/jhps/hnx041

MOVE THE HIP

Supplementary Table 1: Process evaluation of exercise and patient education: key dimensions and methods

Dimensions	Purpose	Data collection	Analysis
Fidelity	Evaluate to which extent the intervention is delivered as intended	Self-report questionnaires to evaluate to which extent the intervention providers could deliver specific content of the intervention using a 100 mm VAS from not possible (0) to always possible (100) on: 1. BORG CR10 to determine difficulty level and repetitions of exercises 2. Participants' acceptability to determine difficulty level and repetitions of exercises 3. Intervention manual to determine correct exercise performance 4. Delivery of patient education on pain mechanisms in hip dysplasia, advice on physical activity, weight loss and motivation and barriers for exercise adherence	Mean or median ability to deliver with associated variation
Dose	Evaluate how much of the intervention that is delivered	Data on number of completed exercise sessions (supervised and home-based session) and data on time used in each supervised exercise session using routine monitoring forms.	Number, median or mean dose with associated variation
Reach	Evaluate if patient characteristics differ between participants and non-participants	Data on sex, age and reason for not receiving a PAO are registered in participants and non-participants using standardised record forms.	Compare patient characteristics between participants and non-participants and different adherence groups
	Evaluate if patient characteristics differ between adherence groups	Data on patient characteristics (i.e. age, BMI, family status, education, CE angle, Tönnis osteoarthritis score, back and hip/groin pain intensity, etc.) are registered in adherent and non-adherent participants using standardised record forms.	

MOVE THE HIP

Mechanisms of change	Evaluate possible modifying mechanisms	One-to-one semi-structured interviews during and at six-month follow-up in 15-20 participants. The interviews focus on previous exercise experiences and expectations to the intervention. They also focus on satisfaction and adaptations following the intervention. Semi-structured focus group interviews with the intervention providers and the expert team. The interviews focus on interactions between the intervention, the intervention providers and the participants in terms of challenges and tailoring based on responses and observations from individual participants.	Theory-driven content analysis
		Reasons for not receiving a PAO, dichotomised into “not offered PAO” (group 1) or “not willing to undergo PAO" (group 2), are registered using standardised record forms.	Compare adherence between groups over six months
Context	Understand the contribution of contextual factors	One-to-one semi-structured interviews at baseline and at six-month follow-up in 15-20 participants in the intervention group. These will focus on the contribution of contextual factors.	Theory-driven content analysis

Abbreviations: CE angle, centre-edge angle; CR, category ratio-scale; PAO, periacetabular osteotomy; VAS, visual analogue scale.

SPIRIT 2013 Checklist: Recommended items to address in a clinical trial protocol and related documents*

Section/item	Item No	Description	Addressed on page number
Administrative information			
Title	1	Descriptive title identifying the study design, population, interventions, and, if applicable, trial acronym	1
Trial registration	2a	Trial identifier and registry name. If not yet registered, name of intended registry	3, 19
	2b	All items from the World Health Organization Trial Registration Data Set	19
Protocol version	3	Date and version identifier	N/A
Funding	4	Sources and types of financial, material, and other support	21
Roles and responsibilities	5a	Names, affiliations, and roles of protocol contributors	1, 20
	5b	Name and contact information for the trial sponsor	N/A
	5c	Role of study sponsor and funders, if any, in study design; collection, management, analysis, and interpretation of data; writing of the report; and the decision to submit the report for publication, including whether they will have ultimate authority over any of these activities	N/A
	5d	Composition, roles, and responsibilities of the coordinating centre, steering committee, endpoint adjudication committee, data management team, and other individuals or groups overseeing the trial, if applicable (see Item 21a for data monitoring committee)	17-18

Introduction			
Background and rationale	6a	Description of research question and justification for undertaking the trial, including summary of relevant studies (published and unpublished) examining benefits and harms for each intervention	3, 5-6
	6b	Explanation for choice of comparators	5
Objectives	7	Specific objectives or hypotheses	5-6
Trial design	8	Description of trial design including type of trial (eg, parallel group, crossover, factorial, single group), allocation ratio, and framework (eg, superiority, equivalence, noninferiority, exploratory)	6
Methods: Participants, interventions, and outcomes			
Study setting	9	Description of study settings (eg, community clinic, academic hospital) and list of countries where data will be collected. Reference to where list of study sites can be obtained	6-7
Eligibility criteria	10	Inclusion and exclusion criteria for participants. If applicable, eligibility criteria for study centres and individuals who will perform the interventions (eg, surgeons, psychotherapists)	7
Interventions	11a	Interventions for each group with sufficient detail to allow replication, including how and when they will be administered	8-12
	11b	Criteria for discontinuing or modifying allocated interventions for a given trial participant (eg, drug dose change in response to harms, participant request, or improving/worsening disease)	10-11, 16
	11c	Strategies to improve adherence to intervention protocols, and any procedures for monitoring adherence (eg, drug tablet return, laboratory tests)	8,12
	11d	Relevant concomitant care and interventions that are permitted or prohibited during the trial	12
Outcomes	12	Primary, secondary, and other outcomes, including the specific measurement variable (eg, systolic blood pressure), analysis metric (eg, change from baseline, final value, time to event), method of aggregation (eg, median, proportion), and time point for each outcome. Explanation of the clinical relevance of chosen efficacy and harm outcomes is strongly recommended	12-15
Participant timeline	13	Time schedule of enrolment, interventions (including any run-ins and washouts), assessments, and visits for participants. A schematic diagram is highly recommended (see Figure)	6-8

Sample size	14	Estimated number of participants needed to achieve study objectives and how it was determined, including clinical and statistical assumptions supporting any sample size calculations	18
Recruitment	15	Strategies for achieving adequate participant enrolment to reach target sample size	6
Methods: Assignment of interventions (for controlled trials)			
Allocation:			
Sequence generation	16a	Method of generating the allocation sequence (eg, computer-generated random numbers), and list of any factors for stratification. To reduce predictability of a random sequence, details of any planned restriction (eg, blocking) should be provided in a separate document that is unavailable to those who enrol participants or assign interventions	7
Allocation concealment mechanism	16b	Mechanism of implementing the allocation sequence (eg, central telephone; sequentially numbered, opaque, sealed envelopes), describing any steps to conceal the sequence until interventions are assigned	7
Implementation	16c	Who will generate the allocation sequence, who will enrol participants, and who will assign participants to interventions	7
Blinding (masking)	17a	Who will be blinded after assignment to interventions (eg, trial participants, care providers, outcome assessors, data analysts), and how	7-8
	17b	If blinded, circumstances under which unblinding is permissible, and procedure for revealing a participant's allocated intervention during the trial	7-8
Methods: Data collection, management, and analysis			
Data collection methods	18a	Plans for assessment and collection of outcome, baseline, and other trial data, including any related processes to promote data quality (eg, duplicate measurements, training of assessors) and a description of study instruments (eg, questionnaires, laboratory tests) along with their reliability and validity, if known. Reference to where data collection forms can be found, if not in the protocol	8, 12-18, Supplementary material
	18b	Plans to promote participant retention and complete follow-up, including list of any outcome data to be collected for participants who discontinue or deviate from intervention protocols	17-18

Data management	19	Plans for data entry, coding, security, and storage, including any related processes to promote data quality (eg, double data entry; range checks for data values). Reference to where details of data management procedures can be found, if not in the protocol	17-18
Statistical methods	20a	Statistical methods for analysing primary and secondary outcomes. Reference to where other details of the statistical analysis plan can be found, if not in the protocol	18-19
	20b	Methods for any additional analyses (eg, subgroup and adjusted analyses)	19
	20c	Definition of analysis population relating to protocol non-adherence (eg, as randomised analysis), and any statistical methods to handle missing data (eg, multiple imputation)	19
Methods: Monitoring			
Data monitoring	21a	Composition of data monitoring committee (DMC); summary of its role and reporting structure; statement of whether it is independent from the sponsor and competing interests; and reference to where further details about its charter can be found, if not in the protocol. Alternatively, an explanation of why a DMC is not needed	17-18
	21b	Description of any interim analyses and stopping guidelines, including who will have access to these interim results and make the final decision to terminate the trial	18
Harms	22	Plans for collecting, assessing, reporting, and managing solicited and spontaneously reported adverse events and other unintended effects of trial interventions or trial conduct	16
Auditing	23	Frequency and procedures for auditing trial conduct, if any, and whether the process will be independent from investigators and the sponsor	18
Ethics and dissemination			
Research ethics approval	24	Plans for seeking research ethics committee/institutional review board (REC/IRB) approval	19
Protocol amendments	25	Plans for communicating important protocol modifications (eg, changes to eligibility criteria, outcomes, analyses) to relevant parties (eg, investigators, REC/IRBs, trial participants, trial registries, journals, regulators)	19

Consent or assent	26a	Who will obtain informed consent or assent from potential trial participants or authorised surrogates, and how (see Item 32)	6-7
	26b	Additional consent provisions for collection and use of participant data and biological specimens in ancillary studies, if applicable	N/A
Confidentiality	27	How personal information about potential and enrolled participants will be collected, shared, and maintained in order to protect confidentiality before, during, and after the trial	17-18
Declaration of interests	28	Financial and other competing interests for principal investigators for the overall trial and each study site	21
Access to data	29	Statement of who will have access to the final trial dataset, and disclosure of contractual agreements that limit such access for investigators	8
Ancillary and post-trial care	30	Provisions, if any, for ancillary and post-trial care, and for compensation to those who suffer harm from trial participation	N/A
Dissemination policy	31a	Plans for investigators and sponsor to communicate trial results to participants, healthcare professionals, the public, and other relevant groups (eg, via publication, reporting in results databases, or other data sharing arrangements), including any publication restrictions	3,19
	31b	Authorship eligibility guidelines and any intended use of professional writers	19
	31c	Plans, if any, for granting public access to the full protocol, participant-level dataset, and statistical code	18-19
Appendices			
Informed consent materials	32	Model consent form and other related documentation given to participants and authorised surrogates	N/A
Biological specimens	33	Plans for collection, laboratory evaluation, and storage of biological specimens for genetic or molecular analysis in the current trial and for future use in ancillary studies, if applicable	N/A

*It is strongly recommended that this checklist be read in conjunction with the SPIRIT 2013 Explanation & Elaboration for important clarification on the items. Amendments to the protocol should be tracked and dated. The SPIRIT checklist is copyrighted by the SPIRIT Group under the Creative Commons "Attribution-NonCommercial-NoDerivs 3.0 Unported" license.