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Review

Management

The efficacy of exercise rehabilitation in restoring physical function following total hip replacement for osteoarthritis: a review

AB Lemmey[1]*, T Okoro[1,2]

Abstract

Introduction

Standard physiotherapy rehabilitation fails to restore normal levels of muscle mass, strength and physical function in patients following elective total hip arthroplasty for osteoarthritis. Consequently, more intense forms of exercise rehabilitation have been advocated for these patients. The aim of this article was to review the controlled trials that have evaluated post-total-hip-arthroplasty exercise interventions aimed at improving function.

Materials and methods

The electronic databases MEDLINE and CINAHL were searched using the following terms: 'total hip arthroplasty/replacement', 'exercise', 'rehabilitation' and 'function'. This search was expanded by hand-checking the reference lists of the studies and reviews identified by electronic scanning.

Results

Thirteen appropriate studies (18 papers) were identified, comprising 8 'early' intervention studies (<5 weeks from surgery) and 5 'delayed' intervention studies.

Conclusion

The studies reviewed suggest that centre-based, but not home-based, exercise rehabilitation are effective in restoring muscle mass, strength and function in total hip arthroplasty patients during the immediate post-surgery phase, and that the efficacy of the centre-based interventions is most likely due to higher training intensity that is facilitated by supervision and access to specialised equipment and facilities. When commencement of training is delayed, however, both home- and centre-based training programs provide significant improvements in patient strength and function.

*Corresponding author
Email: a.b.lemmey@bangor.ac.uk

[1]School of Sport, Health & Exercise Sciences, Bangor University, Bangor, Gwynedd, UK
[2]Department of Orthopaedics, Gwynedd Hospital, Betsi Cadwaladr University Health Board, Penrhosgarnedd, Bangor, UK

Introduction

Total hip arthroplasty (THA) surgery is among the most commonly performed and clinically successful surgical procedures, with the number of operations performed rapidly escalating; that is, 88,984 THAs were carried out in England and Wales in 2011–2012 compared to 51,981 in 2006–2007[1]. Given that end-stage osteoarthritis (OA) accounts for 93% of THA cases[1] and that the prevalence of OA is increasing as the population ages, the number of THA procedures is expected to continue rising worldwide.

Standard physiotherapy rehabilitation programs for post-THA patients, though varying from centre to centre, are usually based on hip range-of-movement (ROM) exercises and functional activities, typically without external loading. However, since persisting muscle loss and functional limitations are characteristic of post-THA patients[2–16], these widely used programs are clearly not optimal. For example, following completion of a standard rehabilitation program, Suetta et al.[14,15] found 13% and 9% reductions in quadriceps muscle cross-sectional area (CSA) on the operated side, 5 and 12 weeks, respectively, following THA. Similarly, Reardon et al.[12] showed that significant atrophy of the quadriceps on the operated side persisted for at least 5 months following THA, despite a structured rehabilitation program that included hydrotherapy sessions, daily hip and thigh exercises and regular walking or cycling, that is, considerably more than most post-THA rehabilitation regimes. Since muscle strength is directly related to muscle mass[14], and current rehabilitation programs are unable to prevent atrophy[4,7,15–18], it follows that strength will be typically compromised in post-THA patients. Suetta et al.[14] found that, despite uncomplicated recovery and 12 weeks of standard rehabilitation following THA, maximal voluntary knee extensor strength on the operated side was reduced by 30% relative to the healthy contralateral leg. Extending the recovery period, Trudelle-Jackson et al.[4] identified 10% to 20% reductions in strength of the hip flexors, extensors and abductors, and the knee extensors on the operated leg compared to the contralateral leg 1 year after THA. Whilst Rasch et al.[3] reported that deficits in hip muscle strength on the operated side relative to the uninvolved side persisted for 2 years following surgery. However, due to the extreme deconditioning and reduced physical-activity-level characteristic of end-stage hip OA patients[19], a better comparison is with community-dwelling age- and sex-matched controls[9,10,14]. In support of this, Frost et al.[10] found that THA patients, 4 to 5 months following surgery, could only generate 60% of the maximal hip flexion force produced by matched, healthy controls. More pertinently, although Bertocci et al.[20]

For citation purposes: *Lemmey AB, Okoro T.* The efficacy of exercise rehabilitation in restoring physical function following total hip replacement for osteoarthritis: a review. OA Musculoskeletal Medicine 2013 Jul 01;1(2):13.

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could identify significant deficits of hip flexion, extension and abduction in THA patients when compared to matched, non-OA controls, this disparity was not apparent when they compared the patient's operated and contralateral sides.

These deficits in strength have serious adverse consequences for THA patients in respect to physical function, maintenance of independence and requirement for revision surgery. Specifically for these patients, reduced leg strength has been associated with poorer gait symmetry, speed and cadence[8,9,11,13–15,21,22], impaired stair-climbing[14,15], chair-rising[14], access to public transport[22], exacerbated risk of falling[9], and loosening of the prosthesis[21,23]. In addition, evidence from the general population demonstrates the links between leg strength and the ability to perform activities of daily living, maintain independence, and reduce falling[24,25]. Given these associations and the inability of standard rehabilitation programs to adequately restore muscle mass, muscle strength and physical functioning, it is not surprising that more intense exercise rehabilitation programs have been widely advocated for post-THA patients[2–4,6–17,19–21,25–31].

The aim of this article is to evaluate the efficacy of exercise rehabilitation programs performed by elective (i.e. hip OA) THA patients following surgery in attenuating muscle loss and restoring strength and physical function. Particular attention is given to the timing of these exercise interventions as there are advocates for very early training interventions[7,11,14,15,17,19,21,27–32] and advocates for training to commence at a later stage, that is, months after THA[4,6,8,10,13,16,22]. Those who favour early rehabilitation point out the need to both counter the dramatic losses of muscle and strength in the immediate post-surgical phase[12] (e.g. strength is observed to decline 3%–4% per day during the initial week of immobilization[7]) and to address the issues of muscle atrophy and strength loss before these deficits peak[14]. In addition, it is argued that early restoration of strength and function reduces post-surgical complications and enables quicker resumption of normal activities[14,21,30]. Conversely, later intervention is favoured by some because there are fewer problems concerning patient transport to centres, and training can be performed at a higher intensity[4,16], that is, at the intensities optimal for increasing muscle mass and strength. Arbitrarily, the time taken by this review to distinguish 'early' and 'delayed' exercise rehabilitation interventions is whether commencement of these programs occurred within 5 weeks of THA, as at this time substantial deficits in muscle mass, strength and functional capacity have been identified in patients who have performed standard physiotherapy rehabilitation[7,10,14,15]. Thus, in keeping with the perspective that rehabilitation interventions are best initiated during the period when deficits are greatest, within 5 weeks of surgery could be viewed as an optimal time for training to commence. In addition, this review considers the efficacy of home-based interventions given that they are more accessible and convenient, especially in the early post-THA period, require less supervision and are considerably cheaper compared with centre-based interventions. Finally, because the length of stay in hospital following THA has been reduced to about 4 days[1], thereby diminishing the role of in-patient rehabilitation, this review only considers interventions performed, at least primarily, following hospital discharge.

Materials and methods

Studies were eligible for review if they met the following criteria: (i) controlled trial of exercise rehabilitation designed to improve physical function in the post-operative period; (ii) subjects had undergone elective THA for hip OA; (iii) the exercise intervention was conducted, at least primarily, after the patient had been discharged from hospital; and (iv) publication was after 1990, and in English. 'Exercise' was defined as structured movements that were of greater intensity and volume than the 'standard physiotherapy' offered to rehabilitating THA patients, with 'standard physiotherapy' varying widely according to centre.

Studies were initially identified by searching MEDLINE and CINAHL databases using a set created with the terms: 'total hip arthroplasty/replacement', 'exercise', 'rehabilitation' and 'function'. This search identified 103 publications, each of which was checked to confirm suitability. To expand the search, bibliographies of eligible studies and appropriate reviews were scanned. When full papers could not be retrieved electronically, the corresponding author was contacted and a reprint requested. For the purpose of this review, interventions were designated 'early' if they commenced within 5 weeks of THA surgery, and 'delayed' if commenced more than 5 weeks post-THA.

Results

Eighteen papers describing 13 controlled, intervention studies were judged as suitable for review. These comprised eight 'early' intervention studies (Table 1, 13 publications) and five 'delayed' intervention studies (Table 2, five publications). Tables 1 and 2 also describe the study design, number of participants, intervention site, follow-up period and hip dislocation/revision rate and briefly outline the exercise intervention, main study outcomes and study limitations. Of the 'early' interventions, six were exclusively centre based[7,14,15,17,19,21,28–32], one was home based[11], and one featured a comparison of centre- and home-based interventions[27]. For the 'delayed' interventions, one was centre based[6],

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Review

Table 1. Characteristics of trials on early (<5 weeks) post-total hip arthroplasty exercise interventions to improve functional outcome

Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise intervention	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
Galea et al. 2008[27]	RCT Centre-based intervention group (n = 11) Home-based intervention group (n = 12)	Centre and home	Inpatient physiotherapy: immediate post-operative period Centre or home exercise intervention: ~4 weeks post-surgery	All participants: standard inpatient physiotherapy with functional tasks (walking, stairs, transfers) for 5 to 6 days (or until functional independence achieved); instructed to continue exercises at home for 3 weeks with up to 4 home visits by physiotherapist Centre group: 2 centre visits per week for 8 weeks. Each supervised session lasting for 45 minutes, and including 7 exercises: functional tasks such as figure-of-8 walking, sit-to-stands, stair climbing, 1-leg balances; hip abduction and heel raises with ankle weights—with instructions for exercise progression. On average, subjects additionally completed 2.7 home-based sessions per week (mean total of 4.7 exercise sessions per week). Home-based sessions included the prescribed exercises, walking, gym work, cycling and swimming at community centres	~12 weeks post-surgery, that is, at conclusion of 8-week intervention	In both groups, all parameters improved significantly from baseline. No differences between groups (Group x Time interaction) at the end of the intervention period Timed up and go: centre 13.5 ± 3.5 seconds (baseline) to 11.1 ± 2.5 seconds (post) vs. home 11.7 ± 1.5 seconds to 9.3 ± 1.3 seconds 6MWT: centre 372 ± 86 m to 427 ± 78.2 m vs. home 375 ± 71 metres to 458 ± 112 metres Stair climb: centre 4.2 ± 1.8 seconds to 3.1 ± 0.4s vs. 3.7 ± 0.6 seconds to 2.9 ± 0.5 seconds WOMAC function: centre 362 ± 232 (baseline) to 168 ± 147 (post) vs. home 399 ± 243 to 223 ± 129 WOMAC pain: centre 62 ± 38 to 40 ± 31 vs. home 77 ± 47 to 56 ± 38	None reported	No standard physiotherapy, only control group No post-intervention follow-up assessments to assess long-term benefits

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Table 1. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise interventioncv	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				Home group: exercises and activities as for centre group, with no advice or further instruction on progression of exercises. On average, subjects completed 5.8 unsupervised exercise sessions per week		WOMAC stiffness: centre 47 ± 23 to 33 ± 30 vs. home 59 ± 46 to 48 ± 26 No Group x Time interaction for gait measures (speed, cadence, stride length)		
Hesse et al. 2003[21]	RCT Intervention (n = 39) Controls (n = 40)	Centre	~3 weeks	All patients: 45-minute individualised treatment on each of 10 consecutive days, including passive physiotherapy (massage, heat ultrasound), group therapy in pool Intervention: Days 1 to 5, 25-minute treadmill training (1000-1500 steps with 15% bodyweight support) after 20-minute physiotherapy (passive hip and knee mobilisation); Days 6 to 10, 35 minutes treadmill training after 10 minutes physiotherapy. Initial speed 0.5 to 1.0 m/s was progressively increased Controls: 45-minute standard physiotherapy (passive hip and knee mobilisation, strengthening	12 months after completion of the intervention	Primary outcome: Harris Hip Score: intervention significantly higher (p < 0.0001), immediately following the intervention (13.6 points) and at 3 months post-surgery (8.9 points) and 12 months post- surgery (16.5 points) vs. controls Secondary outcomes: Mean interval to abandon crutches: 3.2 weeks, intervention vs. 7.9 weeks, controls at end of intervention, for intervention group (vs. controls): Hip extension deficit 6.8° less (p < 0.0001) Gait symmetry 10% greater (p = 0.001)	4 control patients required revision surgery within 12 months due to joint loosening	37.5% (30/80) drop-out rate at 1 year Study included hip fracture patients (2/39 and 3/40 for intervention and control groups, respectively). No separate data provided for these patients No details provided regarding the hip-strengthening exercises prescribed to the controls

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Table 1. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise interventioncv	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				of hip abductor and extensor muscles, gait retraining on floors and steps)		Affected hip abductor stronger ($p < 0.0001$) Amplitude of gluteus medius activity 41.5% greater ($p = 0.001$) These differences in favour of the intervention group persisted (muscle strength, gait symmetry) or even increased (hip extension deficit, mean gluteus medius muscle activity) at 3 and 12 months. Walking velocity over 10 metres did not differ between groups at any time point		
Husby et al. 2009[7], 2010[17]	RCT Intervention (n = 12) Controls (n = 12)	Centre	<1 week	Intervention: standard inpatient physiotherapy plus maximal strength training (5 training bouts per week for 4 weeks involving ~10-minute warm-up then stationary cycling at 50% VO_2 max; strength training with 2 exercises: leg press and hip abduction on operated leg only. 4 sets of 5 repetitions at 85% 1-RM with rest periods of 2 minutes). Loads progressively increased over the training period	12 months post-surgery	At 5 weeks: Bilateral leg press strength (LPS): 40.9% improvement in intervention vs. control group ($p < 0.002$) Operated leg LPS increased by 65.2% vs. controls ($p < 0.002$) Operated leg abductor strength increased by 87% vs. controls ($p < 0.002$) No differences in gait parameters, health-related quality of life outcomes (SF-36), or VO_2 max between groups	None	Lack of adequate sample size to demonstrate significant differences in parameters used to assess work efficiency

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Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise interventioncv	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				Controls: standard inpatient physiotherapy with sling exercise therapy of hip abduction/ adduction, flexion/ extension; low resistance exercises for 1 hour, 3 to 5 days a week for 4 weeks. Patients discharged before 4 weeks had outpatient treatment 3 times per week and were encouraged to do physiotherapy exercises at home 2 times per week		Trend for improvement in work efficiency (p = 0.065, 32%) in the intervention group, heart rate lowered by 11.4% relative to control group during fixed submaximal walk test At 6 months: No significant differences between the groups in muscle strength (bilateral, operated leg and healthy leg: LPS and hip abduction), gait parameters, health-related quality of life outcomes (SF-36), or VO_2 max. Significant improvement in work efficiency (p = 0.034, 29%) in the intervention group, with heart rate (HR) lowered by 11.4% (NS) and VO_2 by 14% (p = 0.048) relative to the control group during sub-maximal walk test At 12 months: No significant differences between the groups in gait parameters, health-related quality of life outcomes (SF-36) or VO_2 max or any strength measures other than leg press for the healthy leg (p = 0.044, 36%) and rate of force		No body composition measures, so whether resistance training reversed muscle atrophy in operated leg is not known Maximum gait speed not assessed

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Table 1. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise interventioncv	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
						development for the operated leg (p = 0.018, 74%), which were superior in the intervention group. Improvements in work efficiency in the intervention group were retained (p = 0.047, 30%) due to relative reductions in VO_2 (p = 0.008, 30%) and HR (p = 0.011, 13%) at fixed sub-maximal workload		
Liebs et al. 2010[29]	RCT Hip arthroplasty subgroup: Intervention (n = 99) Controls (n = 104)	Centre	2 weeks	All patients: standard program of physiotherapy, including ROM exercises, ADL-based activities such as transfers, and walking on stairs and uneven surfaces Intervention: physiotherapist-guided sessions of low-intensity ergometer cycling Sessions 3 per week for ≥3 weeks Controls: no ergometer cycling	24 months post-surgery	Primary outcome: WOMAC function subscale: intervention group score better than controls at 3 months (p = 0.046, 16.4 vs. 21.6) and 24 months (p = 0.019, 9.0 vs. 14.7) Secondary outcomes: WOMAC stiffness subscale: intervention group score better than controls at 24 months (p = 0.047, 13.4 vs. 18.6) WOMAC pain subscale: intervention group better than controls at 3 months (p = 0.049, 11.1 vs. 15.9) Significant improvements also noted in intervention group vs. controls in Lequesne hip and knee	1 dislocation in each group	No objective measures of function assessed Mixed hip and knee arthroplasty population 77% follow-up at 24 months Lack of details regarding cycle ergometer training (e.g. session duration, intensity, form of training, for example, interval or

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Table 1. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise interventioncv	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
						score (at 24 months; p = 0.043), SF-36 (6 and 24 months; p's = 0.011 and 0.004, respectively) and patient satisfaction at 3 months (p = 0.027, 92% vs. 80%)		continuous, progression etc.)
Liebs et al. 2012[30]	RCT Hip arthroplasty subgroup: early intervention (n = 138) Late intervention (n = 142)	Centre	Early intervention: 6th post-operative day Late intervention: 14th post-operative day	In addition to standard physiotherapy, both groups received supervised aquatic therapy: 3 sessions per week, each session 30 minutes duration, till the 5th post-operative week. Sessions aimed at strength, coordination and proprioception training using kickboards, bar floats and float cuffs	24 months post-surgery	Primary outcome: WOMAC function subscale: late intervention group score better, albeit non-significantly, than early intervention group at 3, 6, 12 and 24 months (absolute difference ranged from 0.3 to 3.1, and effect size from 0.01 to 0.19) Secondary outcomes: WOMAC stiffness and pain subscales, Lequesnehip and knee score, S-F36 and patient satisfaction did not differ between the groups at any time point	1 dislocation in each group	No objective measures of function assessed 77% follow-up at 24 months Lack of details regarding aquatic training (e.g. intensity, form of training, progression etc.) No standard physiotherapy, only control group to allow evaluation of the efficacy of aquatic training on function in the initial post-THR period

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Table 1. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise interventioncv	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
Maire et al. 2003[19], 2004[32], 2006[31]; Grange et al. 2004[28]	RCT Intervention (n = 7) Controls (n = 7)	Centre	1 week	All patients: standard program of physiotherapy including 2 hours per day of strength and ROM exercises, aquatics and walking Intervention group: 6 weeks of upper body interval training (IT) on arm ergometer, 3 sessions per week. Each session lasted 30 minutes and involved 6 consecutive periods of 5-minute arm exercise with 4-minute 'base' work and 1-minute 'peak' work. Base was set at ventilator threshold, and peak at maximum power; both determined by an incremental maximal exercise test. Loads for base and peak progressively increased over training period Control group: no upper limb IT	12 months post-surgery	At 2 and 12 months post-surgery, intervention group had significantly better scores, relative to controls, for 6MWT (2 months: 405 metres vs. 259 metres, $p = 0.006$; 12 months: 486 metres vs. 398 metres, $p < 0.05$), WOMAC function scores (2 months: 12 vs. 24, $p < 0.05$; 12 months: 5 vs. 14, $p < 0.05$) and WOMAC global scores (2 months: 15 vs. 25, $p < 0.05$; 12 months: 5 vs. 21, $p < 0.05$) At 2 months, the change in VO_2 peak (+19.2% vs. –3.5%, $p = 0.036$), stride length ($p = 0.018$) and cadence ($p = 0.032$), favoured the intervention group relative to controls. In addition, upper body IT reduced perceived effort and HR while subject performed a fixed sub-maximal workload	None reported	Low number of subjects Only one male participant in each group; therefore, results may only be applicable to elderly female patients No baseline assessment of 6MWT No 12-month assessments of VO_2 peak, stride length or cadence 4 subjects (28.6%) not retested at 12 months
Mikkelsen et al. 2012[11]	RCT Intervention (n = 23) Controls (n = 21)	Home	Day after surgery	Intervention group: 12 weeks of unsupervised daily 'intensified' training. Similar exercises as standard physiotherapy (see below) except that hip extension, flexion and abduction, and knee	12 weeks post-surgery	In both groups, all measures (function: isometric hip abduction strength, standing balance, 10-minute walk, WOMAC function score; WOMAC pain and stiffness scores; health-related quality	None	Intensity of intervention group training cannot be determined from paper

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Table 1. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise interventioncv	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				extension and flexion were all performed against Thera-band resistance), and stepping and 1-legged stance exercises were added. Program featured exercise progression Controls: 12 weeks of standard, unsupervised, physiotherapy exercises: ROM exercises, hip extension, flexion and abduction, and supine and prone knee flexion/extension. No external resistance and no progression Exercise prescription for both groups was 10 repetitions, 2 times per day. In addition, patients were encouraged to walk and cycle		of life: Euro QOL-5 Dimensions; and physical activity: Physical Activity Scale) had improved significantly by 12 weeks relative to baseline There were no differences between the groups for any of the measures		No post-intervention follow-up assessments to assess long-term benefits Only one strength measure (isometric hip abduction strength)
Suetta et al. 2004[14], 2008[15]	RCT Intervention (n = 13) Controls (n = 12)	Centre	Immediate post-operative period	Controls: standard rehabilitation, that is, 15 exercises in 2 parts. 1st part: 6 bed exercises; 2nd part: knee extensions in seated position and hip abduction, knee flexion, step training and calf stretching while standing. The attending physiotherapist added ambulation and transfer during the inpatient stay.	12 weeks post-surgery	Hospital Length of Stay: Intervention: shorter length of stay vs. controls (10 ± 2.4 vs. 16 ± 7.2 days, respectively; $p < 0.05$). Functional performance at 12 weeks: Gait speed: intervention improved maximal gait speed by 30% ($p < 0.001$ vs. baseline). Controls no improvement	None	No assessment of compliance in the SR group No subjective outcome measures

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Table 1. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from THA surgery to intervention start	Exercise interventioncv	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				Performance of these exercises was encouraged in the home setting 2 times per day and attendance was arranged at a physiotherapy department once a week. No external resistance was used when performing SR exercises Intervention: standard rehabilitation plus 12 weeks unilateral progressive resistance training for quadriceps of operated leg. During hospitalisation, exercises included knee extension in seated position with sandbags on ankles (3 sets of 10 repetitions). From about Day 7, leg press and knee extension were performed on machines, 3 times a week. Intensity increased from 50% 1-RM in Week 1 to 65% 1-RM during Weeks 2 to 4, 70% 1-RM for Weeks 5, 6 and to 80% 1-RM for the last 6 weeks. During Weeks 1 to 6, 3 to 5 sets of 10 repetitions, and during Weeks 7 to 12, 2 to 5 sets of 8 repetitions for each exercise		Sit-to-stand: intervention improved by 30% ($p < 0.001$). Controls no improvement. Group difference, $p < 0.05$ Stair climb: intervention improved by 28 % ($p < 0.001$). Controls no improvement Maximal dynamic knee extension strength (peak torque) of operated leg at 12 weeks was up by 30% in intervention group ($p < 0.05$) and unchanged in controls. Group difference, $p < 0.05$. No change for the non-operated leg in either group Quadriceps cross-sectional area (CSA) at 12 weeks: CSA of operated leg was up by 12% in intervention group, and down by 9% in controls (both $p < 0.05$). The non-operated leg was unaffected in both groups		No post-intervention follow-up assessments to assess long-term benefits

RCT, randomised controlled trial; ADL, activities of daily living; 200mFWT, 200-metre fast walk test; IMF, index of muscle function; 6MWT, 6-minute walk test; 1-RM, one repetition maximum; ROM, range of movement exercises; SF-12, Short-form 12; SF-36, Short-form 36; WOMAC, Western Ontario and McMasters University Osteoarthritis scale; RAND 36, Research and Development 36-item health survey questionnaire

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Table 2 Characteristics of trials on delayed (>5 weeks) post-total-hip-arthroplasty exercise interventions to improve functional outcome

Article	Study design: number of participants	Exercise intervention site	Interval from total hip arthroplasty (THA) surgery to intervention start	Exercise intervention	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
Heiberg et al. 2012[6]	RCT Intervention (n = 35) Controls (n = 33)	Centre	3 months	Intervention: supervised group (n = 2-8) 'Walking skill training' (including stair climbing, single-leg stands, lunges, sit-stands, obstacle course, variable speed walking); 12 sessions, 2 sessions per week, each session lasting 70 minutes. Controls: no supervised sessions; encouraged to continue in-patient physiotherapy exercises	12 months post-surgery (~7 months after completion of the intervention)	At 5 months (immediately post-intervention): intervention group had greater improvement vs. controls in 6MWT ($p < 0.001$; ~50 m), stair climb ($p = 0.01$; ~2 seconds), figure-of-8 test ($p = 0.02$; ~3 seconds), IMF ($p = 0.001$; ~3 units), active hip extension ROM ($p = 0.02$), Harris Hip score ($p = 0.05$; ~5 units), and self-efficacy ($p = 0.04$) At 12 months: Significantly greater improvement maintained for intervention group vs. controls for 6MWT ($p < 0.001$; ~46 m) and Stair climb ($p = 0.05$, approximately 1 seconds). Less falls (n = 9 vs. 15, $p < 0.05$) reported for intervention vs. controls	None	26% dropout following randomisation (i.e. failed to commence treatment), but very good retention and treatment compliance thereafter
Jan et al. 2004[22]	RCT Intervention (n = 26) Controls (n = 27)	Home	At least 1.5 years	Intervention group: a daily, 12-week exercise program including hip flexion ROM exercises, bilateral isotonic strengthening of hip flexors, extensors and	Immediately post-intervention	Patients in the intervention group who had good compliance (>50% adherence to protocol, n = 13) showed significant improvement in all measures of strength of	None reported	Subjects in the intervention group were provided with further instructions regarding

Competing interests: none declared. Conflict of interests: none declared.
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Table 2. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from total hip arthroplasty (THA) surgery to intervention start	Exercise intervention	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				abductors using low-resistance ankle weights (2 sets of 10 repetitions) and 1-legged standing (2 sets of 10 repetitions, 5 seconds for each repetition), and 30-minute walking Controls: no exercises		hip abductors, flexors and extensors on both operated and non-operated legs, walking speed and the Harris Hip function score compared to low-compliance exercise (n = 13) and control groups In contrast, the low-compliance exercisers did not differ from the controls in any of the post-intervention measures		exercise when this was requested. No detail is given as to what proportion of the cohort sought additional advice Not stated whether exercise program incorporated progression
Sashika et al. 1996[13]	Non-randomised CT Intervention: Group A (n = 8) Group B (n = 8) Controls (n = 7)	Home	6 to 48 months	Group A: 6 weeks, unsupervised home-based training featuring hip ROM exercises and low resistance (ankle weight) isometric (6-second contraction) strengthening exercises. Training performed daily: 2 sets, 10 to 20 repetitions per set for each exercise. Physiotherapists modified program fortnightly	Immediately post-intervention	Maximal isometric hip abduction torque improved on the THA side in all groups (A and B, $p < 0.01$; controls, $p < 0.05$) relative to baseline, with no differences in change between the groups. This measure on the contralateral side only improved in Group B ($p < 0.01$), and for Group B the change was greater than for Group A	None reported	Low number of subjects Differences between the groups at 6 weeks unclear

Competing interests: none declared. Conflict of interests: none declared.
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Table 2. (Continued)

Article	Study design: number of participants	Exercise intervention site	Interval from total hip arthroplasty (THA) surgery to intervention start	Exercise intervention	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				Group B: same exercises as Group A plus two eccentric exercises for hip abductors while standing on 1 leg (2 sets, 10 repetitions per set). Physiotherapists modified program fortnightly Controls: no exercises		Hip flexor ROM on THA side failed to improve in any group Gait speed and cadence significantly improved in Groups A and B (all $p < 0.05$, except change of cadence in Group B, $p < 0.01$) but not in controls		
Trudelle-Jackson et al 2004[16]	RCT Intervention (n = 14) Controls (n = 14)	Home	4-12 months	Intervention: 8 weeks of weight-bearing exercises (with no external resistance) featuring sit-to-stand, unilateral heel raises, partial knee bends, 1-legged standing stance, knee raises with alternate arm raise, side and back leg raises in standing, unilateral pelvic lowering and raising in standing Controls: 8 weeks of standard physiotherapy exercises featuring 7 basic isometric and active ROM exercises involving glutei, quadriceps and hamstring sets, ankle pumps, heel slides, hip abduction and hip	Immediately post-intervention	Significant improvements ($p < 0.05$) in the intervention vs. control group at 8 weeks for self-perceived function (12-Item Hip Questionnaire); intervention: median change 21.0 (baseline) to 16.0 (8 weeks) $p = 0.01$ vs. control: 19.0 (baseline) to 17.5 (8 weeks), $p = 0.26$ Hip flexor strength (up by 24.4% vs. 7.2%) Hip extensor strength (up by 47.8% vs. 3.6%) Hip abductor strength (up by 41.2% vs. 3.3%) Knee extensor strength (up by 23.4% vs. 1.0%)	None	24 out of 28 patients had primary diagnosis of hip OA. Separate data for the other 4 patients not provided No post-intervention follow-up assessments to assess long-term benefits Lack of objective measures of physical function (e.g. walk tests, sit-to-stands etc.)

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Article	Study design: number of participants	Exercise intervention site	Interval from total hip arthroplasty (THA) surgery to intervention start	Exercise intervention	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				internal and external rotation (all exercises performed supine). Both groups: progressively increased repetitions of exercises; initially 1 set of 15 repetitions, progressing within first 2 weeks to 20 repetitions, and then within 4 weeks to 2 sets of 15 repetitions, and within another 2 weeks to 2 sets of 20 repetitions, which was maintained for the rest of the 8-week program. Encouraged to perform training 3 to 4 times a week		Postural stability (up by 36.8% vs. 0.9%) No difference in fear of falling between groups		
Unlu et al. 2007[8]	RCT Home exercise (n = 9) Centre exercise (n = 8) Controls (n = 9)	Centre and home	12 to 24 months	Home exercise programme (HE): ROM exercises, low-intensity (10% to 30% max isometric torque) isometric and eccentric contractile hip exercises twice daily for 6 weeks, with 2 sets of 10 to 20 repetitions for each exercise	Immediately post-intervention	Maximum isometric abduction torque: improved HE (30 [standard deviation; 12] to 38 [11] ft. lb, p = 0.018) and improved CS (18 [10] to 30 [9.8] ft. lb, p = 0.006), but not controls (18 [10] to 19 [8] ft. lb, p = 0.200)	None reported	No subjective functional score evaluated Lack of specific detail about exercise program (e.g. length of contractions,

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Article	Study design: number of participants	Exercise intervention site	Interval from total hip arthroplasty (THA) surgery to intervention start	Exercise intervention	Follow-up period	Effect of intervention	Dislocations, or re-implant due to joint loosening	Limitations
				Centre-based supervised exercise program (CS): same exercise regime as HE group but training performed under physiotherapist supervision Controls: walking only		Gait speed: significant improvements in the exercise groups only, but no significant difference between groups in terms of improvement. HE (67.8 [23] to 74.4 [24] m/min, p = 0.021), CS (48.5 [4] to 56.7 [5] m/min, p = 0.012), controls (58.0 [12] to 59.8 [14] m/min, p = 0.110) Cadence (number of steps in 1 minute): significant improvements in the exercise groups only, with a significantly better improvement in these vs. controls (p = 0.006), but no difference between the exercise groups. HE (97.7 [18] to 111.0 [17] steps/min, p = 0.011), CS (90.8 [6] to 104.8 [7] steps/min, p = 0.012), controls (87 [16] to 88.2 [16] steps/min, p = 0.119)		nature of resistance, progression etc.) Significant differences between the groups in age, with HE being significantly younger (HE 45.4 [8.7] years; CS 57.8 [7.5] years; controls 52.6 (10.3) years, p = 0.033)

RCT, randomised controlled trial; ADL, activities of daily living; 200mFWT, 200-metre fast walk test; IMF, index of muscle function; 6MWT, 6-minute walk test; 1-RM, one repetition maximum; ROM, range of movement exercises; SF-12, Short-form 12; SF-36, Short-form 36; WOMAC, Western Ontario and McMasters University Osteoarthritis scale; RAND 36, Research and Development 36-item health survey questionnaire

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three were home based[13,16,22], and one involved comparison of centre- and home-based interventions[8].

Discussion

Although there are relatively few studies and no large multi-centre trials on post-THA exercise rehabilitation, discernible trends emerge. With regard to interventions commenced in the initial post-surgery period (Table 1), it appears that centre-based training programs are more efficacious than home-based programs. Of the centre-based interventions, Hesse et al.[21] observed that 10 days of treadmill walking, with 15% bodyweight support, begun within a month of surgery, reduced time on crutches and significantly improved the Harris Hip Score, hip abductor strength, hip ROM, gait symmetry and gluteus medius activity, compared to patients who received standard physiotherapy. Furthermore, these advantages were maintained at 3 and 12 months post-THA. Husby et al.[7,17] showed that 4 weeks of unilateral (operated leg) high-intensity progressive resistance training (PRT; leg press and hip abduction, progressed to loads of 85% 1-repetition maximum [1-RM]), initiated during the first week of recovery, improved leg strength and reduced cardio-respiratory strain during a sub-maximal walk test, relative to standard physiotherapy rehabilitation, and that these effects were generally maintained at 12 months. Liebs et al.[29] found that low-intensity cycling performed thrice weekly for at least 3 weeks produced improved physical function, stiffness and pain (assessed by WOMAC subscales) and quality of life (QoL) more than standard rehabilitation, and that these benefits persisted for at least 2 years. Maire et al.[19,28,31,32] studied THA patients performing high-intensity upper-body interval training for 6 weeks starting a week after surgery. At the end of the intervention period, compared to standard rehabilitation controls, the exercise group scored better for WOMAC function and global scores, the 6-minute walk test (6MWT), stride length and cadence, and aerobic capacity (VO_2 peak), whereas perceived effort and heart rate were lower when undertaking a fixed sub-maximal workload. Unfortunately, not all these assessments were repeated at 12 months post-THA, but those that were (WOMAC function and global, 6MWT) remained better in the training group. Lastly, Suetta et al.[14,15] investigated the effects of 12 weeks unilateral (operated leg) high-intensity PRT initiated whilst the subject is still in the hospital bed. Relative to standard rehabilitation patients, those in the PRT group had a shorter hospital stay and improved function (gait speed, sit-to-stand, stair climbing and maximal knee extension strength) by approximately 30%. The PRT group's improvements in strength and function were associated with quadriceps muscle hypertrophy, whereas the controls, performing standard physiotherapy, experienced continued muscle loss over this period.

In contrast to these centre-based programs, the early home-based intervention of Mikkelsen et al.[11], which featured 12 weeks of twice-daily unsupervised low-intensity resistance training (RT), failed to improve WOMAC function, stiffness and pain scores, QoL, hip abductor strength, standing balance, gait speed and habitual physical activity levels, beyond the levels achieved by standard physiotherapy. These results were replicated in an unpublished study by our group in which elective THA patients (n = 20) who completed 6 weeks of daily, unsupervised low-intensity, bilateral RT at home showed no improvements in knee extensor strength, function (sit-to-stands, gait speed, stair climb, timed-up-and-go [TUG], 6MWT) or leg lean mass relative to patients who received standard physiotherapy (n = 15). In accordance with previous findings[2–4,7,12,14–18] and despite good training compliance for both groups, it is of note that at 12 months, function for patients in our study was generally 30% less than that of age- and sex-matched healthy individuals. An exception to the finding that centre-based interventions are more effective than home-based interventions is provided by Galea et al[27]. In this study, patients approximately 1 month post-THA were randomised to perform the same 8-week exercise program of low-intensity RT and functional tasks either at home, unsupervised, or at a centre, supervised. No between-group differences in the improvements in WOMAC scores, 6MWT, TUG, stair climb or gait parameters were observed. However, since subjects in both groups completed the same training program the design of this investigation failed to address the most likely reason for the apparently greater efficacy of centre-based programs, namely, the higher intensity of exercise these programs typically achieve. An additional flaw of this study was the absence of a standard physiotherapy group, thus preventing any evaluation of whether the exercise program prescribed conferred additional benefit.

Liebs et al.[30] considered how early the commencement of 'early' exercise rehabilitation should be in post-THA patients by comparing the effects of aquatic therapy initiated on either the 14th or the 6th post-surgical day. Despite receiving a week less training, the group that commenced later tended to have better WOMAC function, stiffness and pain scores at the 3-, 6-, 12-, and 24-month post-THA assessments, suggesting that very early training commencements (≤1 week)[7,11,17,19,28,31,32] may be partially counterproductive.

For the delayed interventions (Table 2), there is evidence that both centre-based and home-based exercise interventions can significantly improve function in THA patients. In a centre-based intervention, Heiberg et al.[6] had patients, 3 months after THA, perform 12 sessions of a 'Walking skill training' program. This supervised, group

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training emphasised low-intensity functional and advanced walking activities. Relative to a matched, non-exercising control group, the training group showed greater improvement in the 6MWT, stair climbing, the figure-of-8 test, active hip extension ROM, the Index of Muscle Function (a composite score of mobility, muscle strength, balance/coordination and endurance tests), Harris Hip Score and self-efficacy at the conclusion of the intervention. At 12 months post-surgery (approximately 7 months post-intervention), those who performed the 'Walking skill training' remained significantly better at walking and had experienced fewer falls than controls.

With the home-based exercise interventions, Jan et al.[22] showed that reasonable adherence (≥50% of scheduled sessions completed) to a 12-week, daily program of bilateral hip RT, hip flexion ROM exercises and walking produced improvements in Harris Hip function score, hip abductor, flexor and extensor strength on both sides and walking speed in patients who had received THA at least 1.5 years previously. In contrast, similar patients who either had poor exercise compliance or were randomised to a non-exercise control group showed no improvement in these measures[22]. In an earlier non-randomised trial by Sashika et al.[13], subjects who were 6 to 48 months post-THA, performed a similar low-intensity program[22] twice daily for 6 weeks. The exercisers were divided into two groups ('A' and 'B'), with Group B additionally doing two standing hip abductor exercises. At the conclusion of the training period, the exercise groups, but not the non-exercising controls, had improved gait speed and cadence. Hip abduction strength on the THA side increased in all groups, but on the contralateral side, only in Group B. Trudelle-Jackson et al.[16] compared the effects of 8 weeks of weight-bearing functional and strengthening exercises with those of standard physiotherapy exercises (supine isometric and ROM exercises, with no weight-bearing) in subjects who were 4 to 12 months post-THA. The weight-bearing exercises significantly improved hip abductor, flexor and extensor, and knee extensor strength (range: 23%–48%), postural stability (37%) and self-perceived function, whereas standard physiotherapy failed to change any of these measures (range: 1%–7%). As in the study by Galea et al.[27], Unlu et al.[8] directly compared the effects of the same exercise program performed either unsupervised at home or supervised in a hospital. In addition, this study featured a walking-only control group. The training consisted of low-intensity ROM and isometric and eccentric RT hip exercises performed twice daily for 6 weeks. In contrast to the control group that showed no change, both the home-based and centre-based training groups improved hip abduction strength, gait speed and cadence. The improvement in abductor strength was significantly better for the centre-based relative to the home-based group, whereas the gains in gait speed (16.9% vs. 9.7%) and cadence (15.4% vs. 13.6%) showed a trend in the same direction.

Although not all of the studies reviewed assessed both strength and function, those that did show that functional gains are dependent on increased muscle strength[8,11,13–16,21,22]. More specifically, Husby et al.[17] and Sashika et al.[13] highlight the need to increase hip abductor strength so that gait symmetry can be restored[21], thereby reducing asymmetrical loading that increases fall risk[9] and may contribute to development of OA in the contralateral hip[17]. These conclusions support the rationale that RT should be a key feature of rehabilitation following THA[2–4,7–17,20–22,25–27,29,30]. To maximise gains in strength and muscle hypertrophy it is necessary to perform high-intensity RT, as only maximal or near-maximal loads ensure recruitment of all motor units[33]. Thus, programs such as those used by Husby et al.[7,17] and Suetta et al.[14,15], which featured loads of 85% and 80% 1-RM, respectively, are recommended. However, since performing high-intensity RT requires high levels of motivation, it is encouraging that several of the reviewed studies observed significant increases in strength, and subsequently improvements in function, following low-intensity RT[8,13,16,22]. Interestingly, each of these successful low-intensity RT interventions was performed months after THA, and the attempts by Mikkelsen et al.[11] and ourselves at initiating low-intensity RT interventions within days of surgery have failed to be more effective than standard physiotherapy. Conversely, high-intensity RT programs commenced shortly after THA have proved to be more efficacious in improving strength and function than standard rehabilitation[7,14,15,17]. All of these suggest that timing could be an important consideration when planning rehabilitation programs aimed at rectifying the deficiencies in muscle mass, strength and function that exist in patients following THA, especially when the planned training involves low-intensity exercise, that is, the type of program more likely to be widely acceptable.

As well as RT, there is a strong case for post-THA patients and end-stage OA patients generally also performing aerobic training. Individuals awaiting THA are typically severely deconditioned due to reduced physical activity levels; for example, the mean VO_2 peak of Maire et al's.[19] subjects prior to THA was 9.6 ml/kg/min. As well as improving exercise capacity and function[19,31,32], training-induced increases in VO_2 max also reduce the cardio-respiratory strain involved in performing daily activities[7,17,28] and presumably CVD risk of post-THA patients.

It is important to note that each of the exercise interventions reviewed, whether high or low intensity, home or centre based, or commenced early or late, were considered safe and

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acceptable to post-THA patients. A primary concern regarding mobilisation following THA is prosthetic dislocation. In the studies reviewed, the pooled incidence of dislocation or loosening (Tables 1 and 2) in exercising subjects (n = 604) was 3 (rate = 0.5%) and in standard rehabilitation or non-exercising controls (n = 286) was 5 (rate = 1.7%). Predictably, all dislocations/loosenings occurred during the 'early' (<5 weeks) post-THA period. For this period, the respective rates were exercisers (3/496) = 0.6% and controls (5/196) = 2.6%. Thus, exercise programmes are not associated with increased dislocation rate. Patient acceptability of the programs is evidenced by the very good compliance (>70% of scheduled sessions completed) of all bar one[22] of the home-based interventions[8,11,13,16,27]. This high compliance rate for home-based interventions is encouraging because in the current economic climate, with its accompanying budget constraints, it is unlikely that health authorities will favour provision of expensive hospital- or gym-based outpatient programs that necessarily incur high costs for supervision, transport and facilities. The economic attractiveness of home-based programs, allied to their greater convenience for patients (especially during the initial post-surgery period when travelling is difficult), is unfortunately counterbalanced by the lack of evidence demonstrating efficacy of early home-based exercise programs.

Conclusion

Due to long-standing deconditioning and muscle loss exacerbated by surgery and bed rest, post-THA patients typically have persistent poor physical function that is not adequately corrected by standard physiotherapy rehabilitation. It is clear that more intense exercise programs are required to address this. The studies reviewed suggest that centre-based, but not home-based, exercise rehabilitation are effective in attenuating muscle loss and strength and function deficits in THA patients during the immediate post-surgery phase and that the efficacy of centre-based interventions is most likely due to higher training intensity, which is facilitated by supervision and access to specialised equipment and facilities. When commencement of training is delayed, however, both home- and centre-based training programs provide significant improvements in patient strength and function. A pragmatic compromise between economic and practical considerations may be that post-THA patients are encouraged to regularly perform weight-bearing functional exercises at home during the initial post-surgery period, with the understanding that even good compliance is unlikely to fully restore function, and then when mobility is sufficiently recovered, subjects are encouraged to undertake, either at home or in a community gym, a higher-intensity program featuring both resistance and aerobic training. For this training, supervision, at least initially, should be sought to ensure that training is conducted safely and that workloads are progressed to account for improving fitness. Due to a general lack of studies and the absence of large, multi-centre trials, the veracity of these recommendations awaits confirmation.

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For citation purposes: *Lemmey AB, Okoro T.* The efficacy of exercise rehabilitation in restoring physical function following total hip replacement for osteoarthritis: a review. OA Musculoskeletal Medicine 2013 Jul 01;1(2):13.

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Competing interests: none declared. Conflict of interests: none declared.
All authors contributed to the concept on, design, and preparation of the manuscript, as well as read and approved the final manuscript.
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