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

AB Lemmey1*, T Okoro1,2

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 Cochrane 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.

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 2006–20071. Given that end-stage osteoarthritis (OA) accounts for 93% of THA cases 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 patients2–16, 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 mass14, and current rehabilitation programs are unable to prevent atrophy15,16–18, 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.19 identified 10% to 20% reductions in strength of the hip flexors, extensors and abductors, and the knee extendors on the operated leg compared to the contralateral leg 1 year after THA. Whilst Rasch et al.2 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 patients15, a better comparison is with community-dwelling age- and sex-matched controls19,20. In support of this, Frost et al.19 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...
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, impaired stair-climbing, chair-rising, access to public transport, exacerbated risk of falling, and loosening of the prosthesis. In addition, evidence from the general population demonstrates the links between leg strength and the ability to perform activities of daily living, maintenance of independence and requirement for revision surgery. Particular attention was 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, 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 and one was home based, and one featured a comparison of centre- and home-based interventions. For the ‘delayed’ interventions, one was centre based.

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All authors contributed to the concept on, design, and preparation of the manuscript, as well as read and approved the final manuscript. All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.
### Table 1. Characteristics of trials on early (<5 weeks) post-total hip arthroplasty exercise interventions to improve functional outcome

<table>
<thead>
<tr>
<th>Article</th>
<th>Study design</th>
<th>Exercise intervention</th>
<th>Interval from THA surgery to intervention start</th>
<th>Exercise intervention</th>
<th>Follow-up period</th>
<th>Effect of intervention</th>
<th>Dislocations, or re-implant due to joint loosening</th>
<th>Limitations</th>
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</thead>
<tbody>
<tr>
<td>Galea et al. 2008 [27]</td>
<td>RCT</td>
<td>Centre-based intervention group (n = 11) Home-based intervention group (n = 12)</td>
<td>Inpatient physiotherapy: immediate post-operative period Centre or home exercise intervention: ~4 weeks post-surgery</td>
<td>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</td>
<td>~12 weeks post-surgery, that is, at conclusion of 8-week intervention</td>
<td>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</td>
<td>None reported</td>
<td>No standard physiotherapy, only control group No post-intervention follow-up assessments to assess long-term benefits</td>
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Table 1. (Continued)

<table>
<thead>
<tr>
<th>Article</th>
<th>Study design</th>
<th>Exercise intervention site</th>
<th>Interval from THA surgery to intervention start</th>
<th>Exercise intervention vs. Control</th>
<th>Follow-up period</th>
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<tr>
<td>Hesse et al. 2003&lt;sup&gt;21&lt;/sup&gt;</td>
<td>RCT Intervention (n = 39) Controls (n = 40)</td>
<td>Centre</td>
<td>~3 weeks</td>
<td>All patients: 45-minute individualised treatment on each of 10 consecutive days, including passive physiotherapy (massage, heat ultrasound), group therapy in pool</td>
<td>12 months after completion of the intervention</td>
<td>Harris Hip Score: intervention significantly higher (p &lt; 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</td>
<td>4 control patients required revision surgery within 12 months due to joint loosening</td>
<td>37.5% (30/80) drop-out rate at 1 year</td>
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</table>

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.
Competing interests: none declared. Conflict of interests: none declared.

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<td></td>
<td>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</td>
<td>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</td>
<td>No body composition measures, so whether resistance training reversed muscle atrophy in operated leg is not known</td>
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<td>Liebs et al. 2010&lt;sup&gt;29&lt;/sup&gt;</td>
<td>RCT Hip arthroplasty subgroup: Intervention (n = 99) Controls (n = 104)</td>
<td>Centre</td>
<td>2 weeks</td>
<td>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</td>
<td>24 months post-surgery</td>
<td>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</td>
<td>1 dislocation in each group</td>
<td>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...</td>
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<td>Liebs et al. 2012&lt;sup&gt;10&lt;/sup&gt;</td>
<td>RCT Hip arthroplasty subgroup: early intervention (n = 138) Late intervention (n = 142)</td>
<td>Centre</td>
<td>Early intervention: 6th post-operative day Late intervention: 14th post-operative day</td>
<td>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</td>
<td>24 months post-surgery</td>
<td>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</td>
<td>1 dislocation in each group</td>
<td>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</td>
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<td>RCT</td>
<td>(n = 7)</td>
<td>Centre</td>
<td>1 week</td>
<td>All patients: standard program of physiotherapy, including 2 hours per day of strength and ROM exercises, aquatics and walking, and intervals of upper body exercise on arm ergometer. 6 weeks of upper body interval training, 3 sessions per week. Each session lasted 30 minutes and involved 6 consecutive arm exercises with 4-minute arm exercise between. Base work and 1-minute 'peak' work. Base was set at ventilator threshold, and peak at maximum power, determined by an incremental exercise test.</td>
<td>12 months post-surgery</td>
<td>At 2 and 12 months post-surgery, intervention group significantly better in terms of 6MWT (2 months: 405 metres vs. 259 metres, p = 0.006; 12 months: 486 metres vs. 398 metres, p &lt; 0.05), 6MWT (2 months: 405 metres vs. 259 metres, p &lt; 0.05; 12 months: 486 metres vs. 398 metres, p &lt; 0.05), WOMAC function scores (2 months: 14 points vs. 5 points, p &lt; 0.05; 6 months: 5 points vs. 27 points, p &lt; 0.05), WOMAC global scores (2 months: 15 points vs. 21 points, p &lt; 0.05; 6 months: 5 points vs. 21 points, p &lt; 0.05). At 2 months, the change in VO&lt;sub&gt;2&lt;/sub&gt; 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. In both groups, all measures (function: isometric hip abduction strength, standing balance, 10-minute walk, WOMAC function score; pain and stiffness scores; health-related quality of life) improved over 12 weeks post-surgery.</td>
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<td>RCT</td>
<td>(n = 23)</td>
<td>Home</td>
<td>Day after surgery</td>
<td>Intervention group: 12 weeks of unsupervised daily intense training. Similar exercises as standard physiotherapy (see below) except that hip extension, flexion and abduction, and knee flexion and extension were included in IT. Control group: no upper limb IT</td>
<td>12 weeks post-surgery</td>
<td>No difference in terms of 6MWT (2 months: 405 metres vs. 398 metres, p = 0.08; 12 months: 486 metres vs. 398 metres, p = 0.07), WOMAC function scores (2 months: 14 points vs. 5 points, p = 0.08; 6 months: 5 points vs. 27 points, p = 0.08), WOMAC global scores (2 months: 15 points vs. 21 points, p = 0.08; 6 months: 5 points vs. 21 points, p = 0.08).</td>
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<td>Suetta et al. 2004&lt;sup&gt;14&lt;/sup&gt;, 2008&lt;sup&gt;15&lt;/sup&gt;</td>
<td>RCT</td>
<td>Centre</td>
<td>Immediate post-operative period</td>
<td>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.</td>
<td>12 weeks post-surgery</td>
<td>Hospital Length of Stay: Intervention: shorter length of stay vs. controls (10 ± 2.4 vs. 16 ± 7.2 days, respectively; p &lt; 0.05). Functional performance at 12 weeks: Gait speed: intervention improved maximal gait speed by 30% (p &lt; 0.001 vs. baseline). Controls no improvement</td>
<td>None</td>
<td>No post-intervention follow-up assessments to assess long-term benefits Only one strength measure (isometric hip abduction strength)</td>
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<td>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 ER exercises</td>
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<td>Sit-to-stand: intervention improved by 30% (p &lt; 0.001). Controls no improvement. Group difference, p &lt; 0.05</td>
<td>No post-intervention follow-up assessments to assess long-term benefits</td>
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<td>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</td>
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<td>Stair climb: intervention improved by 28% (p &lt; 0.001). Controls no improvement</td>
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<td>Maximal dynamic knee extension strength (peak torque) of operated leg at 12 weeks was up by 30% in intervention group (p &lt; 0.05) and unchanged in controls. Group difference, p &lt; 0.05. No change for the non-operated leg in either group</td>
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<td>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 &lt; 0.05). The non-operated leg was unaffected in both groups</td>
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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
Compeétions interests: none declared. Conflict of interests: none declared. All authors contributed to the concept, design, and preparation of the manuscript, as well as read and approved the final manuscript.

Review

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

<table>
<thead>
<tr>
<th>Study</th>
<th>Exercise intervention site</th>
<th>Interval from total hip arthroplasty (THA) surgery to intervention start</th>
<th>Exercise intervention</th>
<th>Effect on intervention</th>
<th>Follow-up period</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>Heiberg et al. 2012&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Centre</td>
<td>3 months</td>
<td>Intervention: supervised group (n = 35) ‘Walking skill training’ (including stair climbing, single leg stands, obstacle course, variable speed walking); 12 sessions, 2 sessions per week, each session lasting 70 minutes. Controls: no supervised, encouraged to continue in-patient physiotherapy exercises.</td>
<td>At 5 months (immediately post-intervention): intervention group had greater improvement in 6MWT (p &lt; 0.001; ~50 m), stair climb (p = 0.01; ~2.5 seconds), figure-of-8 test (p = 0.02; ~3 seconds), active hip extension ROM (p = 0.001; ~3 units), active hip flexion (p = 0.002; ~5 units), and Harris Hip score (p = 0.04),</td>
<td>12 months: Significantly greater improvement maintained for intervention group vs. controls for 6MWT (p &lt; 0.001; ~46 m) and Stair climb (p = 0.05, approximately 1 second). Less falls (n = 9 vs. 15, p &lt; 0.05) reported for intervention vs. controls.</td>
<td>26% dropout following randomisation (i.e. failed to commence treatment), but very good treatment compliance thereafter.</td>
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<tr>
<td>Jan et al. 2004&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Home</td>
<td>At least 1.5 years</td>
<td>Intervention group: a daily, 12-week exercise program including hip flexion ROM exercises, bilateral isometric strengthening of hip flexors, extensors andROM exercises. Controls: no supervised sessions; encouraged to continue in-patient physiotherapy exercises.</td>
<td>At 5 months (immediately post-intervention): intervention group who had good compliance (&gt;50% adherence to protocol, n = 13) showed significant improvement in all measures of strength compared to controls.</td>
<td>Immediately post-intervention.</td>
<td>None reported</td>
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Table 2. (Continued)

<table>
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<tr>
<th>Article</th>
<th>Study design: number of participants</th>
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<tr>
<td>Sashika et al. 1996&lt;sup&gt;13&lt;/sup&gt;</td>
<td>Non-randomised CT</td>
<td>Home</td>
<td>6 to 48 months</td>
<td>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</td>
<td>Immediately post-intervention</td>
<td>Maximal isometric hip abduction torque improved on the THA side in all groups (A and B, p &lt; 0.01; controls, p &lt; 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 &lt; 0.01), and for Group B the change was greater than for Group A</td>
<td>None reported</td>
<td>Low number of subjects Differences between the groups at 6 weeks unclear</td>
</tr>
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</table>

Exercise intervention:
- Group A
  - 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

- Group B
  - Controls: no exercises

- Physiotherapists modified program fortnightly

Follow-up period:
- 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

Limitations:
- 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

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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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<td>Trudelle-Jackson et al 2004&lt;sup&gt;46&lt;/sup&gt;</td>
<td>RCT&lt;br&gt;Intervention (n = 14)&lt;br&gt;Controls (n = 14)</td>
<td>Home&lt;br&gt;4-12 months</td>
<td>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&lt;br&gt;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</td>
<td>Hip flexor ROM on THA side failed to improve in any group&lt;br&gt;Gait speed and cadence significantly improved in Groups A and B (all p &lt; 0.05, except change of cadence in Group B, p &lt; 0.01) but not in controls</td>
<td>Immediately post-intervention</td>
<td>Significant improvements (p &lt; 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&lt;br&gt;Hip flexor strength (up by 24.4% vs. 7.2%)&lt;br&gt;Hip extensor strength (up by 47.8% vs. 3.6%)&lt;br&gt;Hip abductor strength (up by 41.2% vs. 3.3%)&lt;br&gt;Knee extensor strength (up by 23.4% vs. 1.0%)</td>
<td>None</td>
<td>24 out of 28 patients had primary diagnosis of hip OA. Separate data for the other 4 patients not provided&lt;br&gt;No post-intervention follow-up assessments to assess long-term benefits&lt;br&gt;Lack of objective measures of physical function (e.g. walk tests, sit-to-stands etc.)</td>
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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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<td>Unlu et al. 2007a</td>
<td>RCT</td>
<td>Centre and home</td>
<td>12 to 24 months</td>
<td>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</td>
<td>Immediately post-intervention</td>
<td>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)</td>
<td>None reported</td>
<td>No subjective functional score evaluated</td>
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<td>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</td>
<td>Postural stability (up by 36.8% vs. 0.9%)</td>
<td>No difference in fear of falling between groups</td>
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<td>Centre-based supervised exercise program (CS): same exercise regime as HE group but training performed under physiotherapist supervision</td>
<td>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)</td>
<td></td>
<td>nature of resistance, progression etc.)</td>
<td>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)</td>
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<td>Controls: walking only</td>
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- 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 McMaster University Osteoarthritis scale; RAND 36, Research and Development 36-item health survey questionnaire.
three were home based\textsuperscript{13,16,22}, and one involved comparison of centre- and home-based interventions\textsuperscript{26}.

**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.\textsuperscript{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.\textsuperscript{2,17} 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.\textsuperscript{29} found that low-intensity cycling performed three 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 effects were generally maintained at 12 months. Liebs et al.\textsuperscript{29} considered that low-intensity exercise intervention of Mikkelsen et al.\textsuperscript{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\textsuperscript{2,7,12,14-18} 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.\textsuperscript{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.
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 measures22. 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 program22 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.14 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.9 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.6,11,13–16,21,22 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 restored11, thereby reducing asymmetrical loading that increases fall risk6 and may contribute to development of OA in the contralateral hip17. These conclusions support the rationale that RT should be a key feature of rehabilitation following THA2–4,7–17,20–22,25–27,29,30 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 units13. Thus, programs such as those used by Husby et al.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 RT6,13,16,22. 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 rehabilitation7,14,15,17.

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 VO2 peak of Maire et al.19 subjects prior to THA was 9.6 ml/kg/min. As well as improving exercise capacity and function19,31,32, training-induced increases in VO2 max also reduce the cardio-respiratory strain involved in performing daily activities7,17,28 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 necessary to perform high-intensity RT, or late, were considered safe and
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/loosening 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 one22 of the home-based interventions9,11,13,16,27. 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.

References


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