Rehabilitation after total hip arthroplasty: a systematic review of controlled trials on physical exercise programs

M. DI MONACO 1, F. VALLERO 1, R. TAPPERO 2, A. CAVANNA 1

Total hip arthroplasty (THA) is among the most widely performed procedures in orthopedic practice and with the aging of the population, the number of persons who require THA is on the rise. THA has revolutionized the care of patients with end-stage joint disease, leading to pain relief, functional recovery, and substantial improvement in quality of life. However, long-term studies indicate persistence of impairment and functional limitation after THA, and the optimal rehabilitation protocols are largely unknown. The aim of this paper was to systematically review the controlled trials published on the effectiveness of physical exercise programs after THA. Nine studies were retrieved from MEDLINE and reviewed. Results show that the physical exercise protocols most frequently used after THA in the early postoperative phase are neither supported nor denied by clinical controlled trials. Convincing evidence for the effectiveness of single interventions in addition to usual exercise programs exists for each of the three following options: treadmill training with partial body-weight support, unilateral resistance training of the quadriceps muscle (operated side), and arm-interval exercises with an arm ergometer. In the late postoperative phase (operation interval > 8 weeks) exercise programs consistently improve both impairment and ability to function. Weight-bearing exercises with hip-abductor eccentric strengthening may be the crucial component of the late-phase protocols. Despite limitations, we conclude that three main suggestions emerge from controlled trials on physical exercise after THA: early postoperative protocols should include additive interventions whose effectiveness has been shown. Late postoperative programs are useful and should comprise weight-bearing exercises with hip-abductor eccentric strengthening.

KEY WORDS: Arthroplasty, replacement, hip - Osteoarthritis - Exercise - Prosthesis implantation - Rehabilitation.

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postural stability, and limited flexibility. Functional limitations include reduced walking speed, and lower ratings on various assessment tools used to measure ability to function. Notably, muscle weakness and functional deterioration were reported in THA patients who developed loosening of the hip components, and a causal role of persistent impairment and poor function in affecting implant longevity was hypothesized, although it cannot be definitively established by observational studies. \textsuperscript{15, 16} Rehabilitation after THA is expected to avoid impairment persistence and to optimize functional recovery. Consequently, people with THA largely attend rehabilitation services. \textsuperscript{17-19} A very recent review showed that following THA, early multidisciplinary rehabilitation improved outcomes at the level both of activity and participation when compared with routine rehabilitation. \textsuperscript{20} The authors showed a significant advantage due to early multidisciplinary intervention for both inpatient and home-based rehabilitation. However, no evidence-based guidelines on rehabilitation after THA are available worldwide, and detailed rehabilitation protocols, including exercise type, duration of each session, time interval between sessions, and specific equipment required, strictly based on the hierarchy of evidence, have not been published. In everyday practice it is common to find different rehabilitation protocols, either from physiatrist to physiatrist or from surgeon to surgeon, even within the same geographic area or the same institution. We wondered what evidence supports postoperative exercise programs usually performed in clinical practice, and what exercise programs are supported by strong evidence from controlled trials. We tried to address this issue by systematically reviewing all the controlled trials published on the effectiveness of specific physical exercise programs versus control exercise programs after total hip replacement surgery.

**Materials and methods**

Criteria for considering studies for this review

Studies were eligible for review if they met the following criteria: 1) clinical trials with a control group; 2) interventions regarded type and/or intensity of physical exercises; 3) descriptions of physical exercise protocols used both for intervention groups and controls were available. Descriptions should include exercise type, duration of each session, time interval between sessions, and specific equipment required and should allow the reader to repeat the exercise program as described by the authors. Alternatively, intensity may be the only variable described in detail, provided that exercise types were the same in intervention groups and controls and that exercise protocol was the only (or the main) variable discriminating intervention groups and controls; 4) outcome measures included at least one among impairment, activity, health-related quality of life, or length of stay in hospital; 5) language was English; 6) all patients underwent THA, or data from the subgroup with THA were analyzed separately.

We did not select studies on the basis of their methodological quality, although we judged each study using the Physiotherapy Evidence Database (PEDro) scale. This is a reliable scale developed to rate the quality of randomized controlled trials (RCTs) evaluating physical therapist interventions. \textsuperscript{21, 22} The PEDro score is determined by counting the number of checklist criteria that are satisfied in the trial report. Overall, PEDro score derives from 10 criteria (out of the 11 criteria of the checklist): random allocation, concealed allocation, comparability of groups at baseline, subject blinding, therapist blinding, assessor blinding, >85% of the patients evaluated at follow-up, intention-to-treat analysis, between-group statistical comparisons, point estimates and measure of variability provided. No limitations were applied as for date of publication. All potentially eligible studies were evaluated for inclusion by one reviewer, without prior consideration of the results. Selected studies were then evaluated by all the authors of this review. Conflicts on eligibility were resolved by discussion.

Search strategy for identification of studies

We conducted a MEDLINE search of articles published in the English language literature by using the following key words: “hip, arthroplasty, rehabilitation”. Further searches were performed by substituting either “prosthesis” or “replacement” for “arthroplasty” and “exercise” for “rehabilitation”. To expand our search for additional articles of interest, we also hand-searched the bibliography of all studies included in this review. Furthermore, we evaluated the “related articles” (by using Pubmed) for each study included in this review.
Description of included studies and of 3 studies excluded after discussion

On the whole, our searches led to 1102 articles. Twelve studies were selected for this review at the first step by adopting our inclusion criteria. Three of these 12 were excluded from this review after discussion among the authors of this article.23-25

Finally, 9 studies that met our inclusion criteria were identified. Five of these 9 studies dealt with early-phase exercises (operation interval <8 weeks), whereas the other 4 regarded late-phase exercises (operation interval >8 weeks).

We summarized the main characteristics of the 9 studies in a single structured table (Table I). This compilation allowed us to examine the variation in patient characteristics, study quality, intervention, and outcome measure assessed.

Results

Interventions performed in the early postoperative phase (operation interval <8 weeks)

Hesse et al.26 showed that treadmill training with partial body-weight support significantly improved the Harris hip score assessed at the end of a ten-day training. The difference in favor of the treatment group persisted at the 3- and 12-month follow-up. The Harris hip score consists of 6 weighted categories: pain, limping, use of technical aids for daily mobility, maximum walking distance, competence in some daily activities, and passive hip range of motion. Within the Harris hip score, the pain and maximum walking distance categories revealed the largest differences in favor of the treadmill group. Hip extension deficit, gait symmetry, hip-abductor strength, and the amplitude of gluteus medius activity assessed by electromyography were all better in the treatment group, with significant differences that persisted during the follow-up period. Furthermore, patients in the treatment group abandoned their crutches far sooner than controls (mean operation intervals were 3.2 and 7.9 weeks, respectively). Among the outcome measures, only gait speed did not significantly differ between the two groups. A safety concern raised, because one patient in the treatment group died of pulmonary embolism during the treatment phase: the firm pressure of the harness around patient’s thighs possibly played a causal role in the genesis of deep vein thrombosis and pulmonary embolism. The Authors were aware of a possible pro-thrombotic risk and excluded from their study the patients at highest risk, i.e., those with a history of deep vein thrombosis in the previous 6 months. The patient who died suffered from a deep vein thrombosis one year before study onset. Also, a possible beneficial effect of treadmill training was suggested as for arthroplasty stability, because loosening of the prosthesis was found in 4 patients from the control group, whereas none of the patients from the intervention group developed loosening at the one-year follow-up.

Suetta et al.27 showed that unilateral resistance training of the quadriceps muscle (operated side) exerted several beneficial effects when started just after surgery and performed over a 12-week period. Hospital stay length was significantly shorter, with a relevant reduction (10±2.4 days versus 16±7.2 days in the control group, mean ± SE; P<0.05). Functional performance significantly increased by about 30% (within group comparison), whereas it did not change in the controls. Among functional performance tests, a significant between-group difference was observed for the sit-to-stand test (P=0.02). Quadriceps muscle cross-sectional area significantly increased versus baseline (12%; P<0.05), whereas it significantly decreased by 9% in the controls (P<0.05). A significant between-group difference was observed (P<0.001). Peak quadriceps muscle torque significantly increased versus baseline, whereas it did not change in the controls. A significant between-group difference was observed (P<0.001). Notably, all the outcome measures assessed by Suetta et al. significantly improved in the group of patients treated with unilateral resistance training. No training-related complications were observed. In the RCT by Suetta et al., a further group was included: they were treated with neuromuscular electrical stimulation (NES). This group showed a significant increase by about 20% in functional performance versus baseline (P<0.05). The change in the sit-to-stand test was significantly greater than in the control group (P=0.03). However they did not show significant improvements in the length of stay in hospital, cross sectional muscle area, and quadriceps muscle peak torque versus baseline (within group comparison). Furthermore, NES group showed a significantly lower increase in muscle peak torque than the resistance training group (P=0.001) and a significantly lower increase in cross-sectional muscle area (P<0.001).
### Table I.— Characteristics of the nine controlled trials included in this review.

<table>
<thead>
<tr>
<th>Study</th>
<th>Methods</th>
<th>Participants</th>
<th>Intervention</th>
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<th>PEDro score and dropouts</th>
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<tr>
<td>Hesse 2003 26</td>
<td>RCT</td>
<td>Duration: 1 year. Blinding: assessor.</td>
<td>80 patients from 1 center, age &lt;75 years, first time unilateral fully-loadable THA for osteoarthritis or hip fracture, ability to walk reciprocally with 2 crutches, gait symmetry &lt; 0.85, no further orthopedic or neurologic diseases affecting gait, no history of deep vein thrombosis or symptomatic heart disease in the previous 6 months. Operation interval about 3 weeks. Mean age: 64.7 years in the intervention group and 63.5 years in the controls.</td>
<td>Two groups. Intervention group: treadmill training with partial body-weight support by a harness suspended by a set of pulleys for 25 to 35 minutes a day for 10 working days + 20 to 10 minutes of passive joint mobilization. Control group: 45 minutes a day of passive joint mobilization, strengthening of hip abductor and extensor muscles and gait retraining. Additionally, both groups received 30 minute-sessions of occupational therapy and passive physical therapy + 25-minute sessions of group therapy in the swimming pool daily.</td>
<td>Primary: Harris hip score. Secondary: hip extension deficit (from Harris hip score), gait velocity, gait symmetry, hip abductor muscle strength (by using the Medical Research Council Scale grade), hip abductor mean electromyographic activation, interval from surgery to abandoning crutches.</td>
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<tr>
<td>Suetta 2004 27</td>
<td>RCT</td>
<td>Duration: 12 weeks Blinding: assessor for muscle cross-sectional area.</td>
<td>36 patients from 1 center, aged 60 years and older, first time unilateral THA for osteoarthritis, no cardiological, neurological or cognitive problems. No comorbidity or comorbidity without systemic affection. Operation interval: about 1 day. Mean age: 69 years in both the intervention groups, 68 years in the control group.</td>
<td>Three groups. Intervention group: standard rehabilitation + unilateral progressive training for the quadriceps muscle of the operated leg. First week: daily knee extension exercises in seated position with sandbags strapped to the ankle. Weeks 2 to 12: leg-press and knee-extension machines 3 times per week; training intensity from 20 repetition maximum to 8 repetition maximum. During each session patients performed 3 to 5 sets of 8 to 10 repetitions. Neuromuscular Electrical Stimulation (NES) group: standard rehabilitation + NES for 1h daily (pulse rate 40Hz, pulse width 0.25 ms, stimulations</td>
<td>Hospital length of stay, quadriceps muscle cross-sectional area (by computed tomography), speed in 3 functional performances (gait, stair-climbing, rising from a chair), isokinetic maximal knee extension moment</td>
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<td>Maire 2004</td>
<td>RCT. Duration: 2 months. Blinding: none.</td>
<td>14 patients from 1 center, aged 65 years and older, first time unilateral THA for primary osteoarthritis, no medications that could interfere with exercise testing and training, no diseases other than osteoarthritis. Operation interval: 1 week. Mean age: 75.1 years.</td>
<td>Two groups. Intervention group: standard rehabilitation + arm-interval exercise program with an arm ergometer. The program started one week after surgery. It consisted of a 30-minute session, 3 times per week, for 6 weeks. One session consisted of 6 consecutive periods of 5 minutes, including 4 minutes of rather low work, and 1 minute of peak work. The loads were progressively increased during the training period. Control group: standard rehabilitation (muscle strength, range of motion, aquatics, walking), 2 hours per day.</td>
<td>Western Ontario and McMaster Universities (WOMAC) osteoarthritis index. Six-minute-walk test. Incremental exercise test on an arm crank ergometer.</td>
<td>PEDro score: 4. Dropouts: none declared.</td>
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<tr>
<td>Jesudason 2002</td>
<td>RCT. Duration: 4 days. Blinding: assessors.</td>
<td>42 patients from 1 center, first time unilateral elective THA, able to understand English language, able to co-operate, able to walk prior to admission, full weight-bearing status post-operatively. Operation interval: 3 to 4 days. Mean age: 69.1 years in the intervention group and 69.3 years in the control group.</td>
<td>Two groups. Intervention group: standard mobilization + bed exercises aimed at increasing strength and range of motion. The exercises were performed in supine position and comprised hip and knee flexion, hip and knee extension to neutral, hip abduction, hip adduction to neutral, ankle dorsiflexion and plantar flexion, static quadriceps contraction, inner range quadriceps exercises over a rolled up towel. Each exercise was repeated for 10s followed by 20s of rest. Controls = standard rehabilitation (active exercises without resistance + stretching exercises for 1h daily. Training in transfer situations and ambulation).</td>
<td>Severity of resting pain by using a visual analogue scale. Range of hip flexion and abduction in the supine position. Functional status by using the Iowa Level of Assistance Scale. Length of stay in hospital.</td>
<td>PEDro score: 7. Dropouts: 2 for each group.</td>
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(To be continued)
Table I.— Characteristics of the nine controlled trials included in this review (Continues).

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<td>Munin 1998[31]</td>
<td>RCT</td>
<td>35 patients from 1 center, elective THA, 70 years of age or older and living alone (or 70 years of age or older with 2 or more comorbid conditions, or any age with 3 or more comorbid conditions), no medical or surgical complications occurring post-operatively and precluding scheduled rehabilitation programs. Operation interval 3 days. Mean age: 75.7 years in the intervention group and 74 years in the control group.</td>
<td>Two groups. Intervention group began intensive rehabilitation on post-operative day 3. Intensive rehabilitation consisted of 2 sixty-minute physical therapy and 2 sixty-minute occupational therapy sessions daily (weekdays only), and a single 30-minute physical therapy session on Saturdays. Control group began intensive rehabilitation on post-operative day 7. From day 3 to 7 the controls received two 30-minute physical therapy sessions + a single 30-minute occupational therapy session during weekdays only, and a single 30-minute physical therapy session on Saturdays.</td>
<td>Length of stay in hospital. Hospitalization cost. General health status by using the RAND 36-item health survey I (at the 16-week follow-up). Functional score by using the functional status index (at the 16-week follow-up) and a subset of the functional independence measure (at day 6 to 10 postoperatively).</td>
</tr>
<tr>
<td>Jan 2004[32]</td>
<td>RCT</td>
<td>58 patients from 1 center, primary THA by the same surgeon using the anterolateral approach, no prosthesis failures, no revisions, being able to walk independently without assistive devices, no major comorbidities (cardiopulmonary, neurologic or cognitive). Operation interval at least 1.5 years. Mean age: 59.5 years in Two groups. Intervention group underwent a 12-week daily home exercise program. It consisted of hip flexion range of motion exercises for both hips (2 sets by 10 repetitions/set), isometric exercise for bilateral hip flexors, extensors and abductors with constant low-resistance weight tied on the ankle (2 sets by 10 repeti-</td>
<td>Isometric muscle strength of bilateral hip extensors, flexors, and abductors. Functional status by using the functional activity part of the Harris hip score. Free and fast walking speed over 3 different terrains.</td>
<td>PEDro score: 6. Dropouts: 3 from the intervention group and 2 from the controls.</td>
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<td>Trudelle-Jackson 2004 33</td>
<td>RCT</td>
<td>34 patients from 1 center, THA, no revisions, no pain at weight bearing, no low back pain at the time of the study, no diagnosed vestibular problems, no central or peripheral nervous system diseases, no cognitive impairment. Operation interval: 4 to 12 months. Mean age: 59.4 years in the intervention group and 59.6 years in the control group.</td>
<td>Two groups. Both groups underwent a 8-week home exercise program. Subjects were instructed to 15 repetitions of each exercise 3 to 4 times a week. The number of repetitions progressively increased, reaching 2 sets of 20 repetitions by the end of the 8-week program. Good form and slow, controlled movement were emphasized for both groups. In the intervention group the exercise program consisted of 7 weight bearing exercises: sit to stand, unilateral heel raises, partial knee bends, 1-legged standing balance, knee raises with alternating arm raises, side and back leg raises in standing and unilateral pelvic raising and lowering in standing. The control group followed an exercise program of 7 basic isometric and range of movement exercises, including gluteal muscles sets, quadriceps sets, hamstring sets, ankle pumps, heel slides, hip abduction in supine, and hip rotations in supine.</td>
<td>Self assessed physical function by using the 12-item Hip Questionnaire. Postural stability by using a lightweight force platform that tracks changes in the center of pressure over time as the subjects stand erect over 1 feet. Maximal isometric strength produced by hip flexors, abductors, and extensors, and knee extenders. Fear of falling by asking 2 simple questions.</td>
<td>PEDro score: 5. Dropouts: 4 from the intervention group and 2 from the controls.</td>
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<tr>
<td>Sashika 1996 34</td>
<td>Nonrandomized CT</td>
<td>23 patients from 1 center. THA for hip osteoarthritis, no pros-</td>
<td>Three groups. Intervention groups (A and B) underwent a 6-</td>
<td>Hip range of movement, gait quality, pain, activities of daily living</td>
<td>PEDro score: 4. Dropouts: none declared.</td>
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(To be continued)
Maire et al. investigated the efficacy of an arm-interval exercise program with an arm ergometer in a small RCT. At a 2-month follow-up patients from the intervention group showed a significantly higher VO$_2$ peak value than controls, and covered a significantly longer distance in the 6-minute-walk test (mean distance...
Interventions performed in the late postoperative phase (operation interval > 8 weeks)

Jan et al.32 showed that a 12-week home exercise program increased hip muscle strength, fast walking speed, and functional score (functional subscore of the Harris hip score). The effects were significant in the subgroup of patients from the intervention group who were highly compliant (practice ratio >50%), whereas the subgroup with low compliance and the controls exhibited no significant improvements (within group comparison). The highly-compliant group showed a significant improvement in muscle strength, walking speed, and function versus both low-compliant patients and controls (between group comparison). Patients from the low-compliance group showed a significant improvement in ability to function versus controls (between group comparison). Overall, compliance was modest: among the 26 patients from the intervention group who completed the study, 13 showed a practice ratio <50%. Notably, the exercise program took about 60 minutes daily, for 12 weeks.

Trudelle-Jackson et al.33 showed that a 8-week home exercise program including weight bearing exercises aimed at increasing strength and balance (intervention) but not on range of movement and isometric exercises (control) significantly increased self-perceived function (within group comparisons). No significant differences in self-perceived function were shown between the two groups. Muscle strength (at all the sites assessed) and postural balance significantly increased in the intervention group but not in the control group (within group comparisons). Also, differences between the two groups in muscle strength and postural balance were significant at the end of the study (between group comparison). Fear of falling was not significantly changed in both groups. All the patients included in this study were surgically operated on by using an anterolateral approach (although a specific surgical approach was not an inclusion criterion).

Sashika et al.34 showed in a nonrandomized controlled trial that a 6-week home exercise program including hip range of motion exercises, isometric and eccentric strengthening exercises increased strength of hip abductors, fast walking speed and cadence (within group comparisons). In the intervention group without eccentric strengthening exercises, improvements were seen in walking speed and cadence, whereas muscle strength increase was seen in the operated side only. Notably, muscle strength in

No significant differences in the Western Ontario and McMaster Universities (WOMAC) osteoarthritis index were shown between the two groups, whereas both groups significantly improved in WOMAC score. Also, the WOMAC subscores (pain, stiffness, and physical function) did not significantly differ between the two groups. Results of a one-year follow-up of the same study have been published afterwards: a confirmation of the improvement at the 6-minute-walk-test was obtained.29

Jesudason et al.30 investigated the efficacy of bed exercises begun 3 to 4 days postoperatively and performed for a very short period (till day VII or VIII postoperatively). The Authors emphasized the absence of beneficial effects due to bed exercises and early mobilization compared with early mobilization alone. Indeed, no differences in length of stay in hospital, pain severity and functional score were shown. However, 2 of the 6 categories of the functional score (i.e., walk 15 feet and climbing stairs) were significantly better in the treatment group (between group comparison) and a trend toward an overall better functional score (that also includes supine to sitting, sitting on the edge of the bed to standing and walking speed over 13.4 meters) was observed (P=0.07). Data from the assessment of hip range of motion showed a non-significant trend toward a better outcome in the treatment group for hip flexion.

Munin et al.31 addressed the role of early intensive rehabilitation in a sample of patients at high risk. Although the patients included in the study underwent either hip or knee arthroplasty, data for people with hip replacement were analyzed separately and looked similar to those of the patients with knee arthroplasty. The group performing early intensive rehabilitation showed a shorter length of stay in hospital (the mean was 12.2 days versus 14.8 days in the control group) and a lower total cost for surgery and rehabilitation. Patients from the intervention group exhibited more rapid attainment of short-term functional milestones between days 6 and 10 postoperatively, but these differences were not significant when data were stratified for surgery type. Both functional self-assessment and general health status did not differ between the two groups at the 16-week follow-up. No concern for complications due to early intensive treatment was reported. Dropouts were similar in the two groups, and early intensive treatment was overall well tolerated.

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the operated side increased in the control group, too. The hip score of the Japanese Orthopedic Association (a weighted sum of subscores from evaluations of pain, hip range of motion, gait quality, and activities of daily living) assessed at the end of the study was not shown in the paper (despite it was included among the outcome measures assessed). None of the groups improved as for range of motion of hip flexion.

Unlu et al.\textsuperscript{35} evaluated the same exercise program used by Sashika et al.\textsuperscript{34} including eccentric strengthening exercise, with two differences versus the previous trial: the study by Unlu et al. was randomized (while Sashika's one was non randomized), and there were two settings for the intervention group (a subgroup followed a home-exercise program as in the previous study, another one performed the same exercises in hospital, under direct physiotherapist supervision). Both intervention groups showed a significant increase in hip abductor muscle torque (within group and versus controls). The increase was significantly higher in the group with physiotherapist supervision than in the home exercise group (between group comparison). Gait speed and cadence significantly increased in both the intervention groups (within group and versus controls) whereas no significant differences where shown between the group with physiotherapist supervision and the home exercise group. Unfortunately, a substantial difference in age was seen among the three groups at baseline.

**Discussion**

Interventions performed during the early postoperative phase (operation interval 1-8 weeks)

Comments on the exercise programs tested in the controlled studies we reviewed should take into account the lack of a standard protocol agreed upon for rehabilitation after THA. Although several authors called “standard” the protocol performed by their controls, they simply described the exercises usually performed in their own institution. Given the lack of a standard protocol, it is challenging to compare different studies and to judge whether the results were weakened (or invalidated) by a not proper exercise program performed by control subjects. Most frequently, early postoperative exercise protocols include ankle pumps, quadriceps and gluteal sets, active exercises for hip range of motion, early mobilization including transfer training (bed-to-standing and toilet transfer), gait training with proper devices, instructions and training in activities of daily living.\textsuperscript{17, 18, 36-40} None of the 5 studies we reviewed addressed the issue of the effectiveness of the most frequently used protocols as briefly described above, because no control groups without rehabilitation were adopted in the 5 studies. This likely reflects the general belief that rehabilitation is useful in the early postoperative phase, although there are no evidence-based studies proving rehabilitation usefulness and defining the best interventions. Jesudason et al.\textsuperscript{30} evaluated the effectiveness of a single component of the usual exercise protocol, i.e., bed exercises performed in supine position without resistance between days 3-4 and 7-8 post-surgery. The authors emphasized the absence of beneficial effects due to bed exercises and early mobilization compared with early mobilization alone. It may be concluded that early mobilization is the gold standard for achieving functional recovery after THA, and that bed exercises are not required.\textsuperscript{35} However, the study by Jesudason et al. seems not to provide adequate evidence to support the conclusions driven by the authors. According to the authors’ scope, their bed exercise program was aimed at increasing range of movement and/or muscle strength. Indeed, active range of movement exercises were performed for hip, knee and ankle. However, the bed exercises without resistance seemed not designed to increase muscle strength. Unfortunately, strength measurements were performed neither before nor after the intervention. This is a relevant limitation, because strengthening exercises may be a pivotal component of the exercise programs after THA.\textsuperscript{17, 18, 29, 36-40} Furthermore, study design was characterized by several limitations, listed below. Study duration was very short (4 days). Statistical power seemed not adequate for negative conclusions, given small sample size, variability of the outcome measures, and dropouts. Power calculation was provided for 40 patients (but data were available only for 38 of them) and for a type I error of 0.05 (but a more stringent level of significance was chosen by the authors, given multiple comparisons). A trend toward a better outcome in favor of the group performing bed exercises clearly emerged from the study. Overall, we conclude that the rehabilitation protocols most frequently used after THA are neither supported nor denied by clinical controlled trials.

Three of the 5 trials we reviewed evaluated the
effectiveness of single additive components of the early-phase rehabilitation protocols. Each of these three studies provided convincing evidence for the effectiveness of the single additive intervention evaluated. Hesse et al., showed that treadmill training with partial body-weight support significantly improved both impairment and function. Some limitations of this study, including high number of dropouts and limited assessment of potential confounders, have been emphasized. However, the comprehensive quality score of the study was high. Impressively, beneficial effects due to a ten-day intervention performed in the early postoperative phase persisted at a one-year follow-up. Changes were clinically relevant and regarded all the outcome measures assessed, but walking speed. Despite people in the control group but not those from the intervention group performed an exercise program based on strengthening exercises for both hip extensors and abductors, patients in the intervention group developed stronger hip abductors and greater hip extension than controls. So, treadmill training with partial body weight support seems to be a tool to maximize strength and movement recovery, without performing specific exercises. This result may lead to move beyond the usual programs based both on “non-functional” exercises for muscle strength and hip range of movement and “functional” activities, including gait training. This study suggests that a task-specific, repetitive approach consisting of numerous complex gait cycles optimizes recovery of strength, range of movement and function. However, two relevant limitations make this conclusion weak. Firstly, the authors do not describe in detail the strengthening exercises performed by their control subjects and the reader cannot generalize the results to every strengthening program. Secondly, the study does not include a control group with intensive gait training without partial body weight support. So, the beneficial effect observed in the intervention group may simply depend on gait, irrespectively of the use of harnesses and pulleys. The safety concern on deep vein thrombosis and pulmonary embolism imposes an accurate selection of low-risk patients for this treatment option. Siem et al. showed that unilateral resistance training of the quadriceps muscle improved both impairment and function and shortened the length of stay in hospital. This is the only paper included in this review that clearly indicated exercise intensity and its progressive increase by using repetition maximum units, thus reassuring the readers on optimal exercise intensity and generalizability of the results. Because controls performed exercises without resistance, this study suggests that resistance training is a crucial component of the exercise program after THA. Resistance training was performed unilaterally (operated side, only). This may be proper, because the operated side is characterized by a greater strength reduction than the contralateral side. However, it is not possible to predict whether bilateral training could lead to a further improvement in function and reduction in the length of stay in hospital. In the same study, the group treated with NES showed a modest improvement in functional ability versus controls, but a worse outcome than the group treated with resistance training. NES is expected to increase muscle mass, whereas its effects on voluntary muscle strength may be questionable. Unfortunately, NES did not significantly increase muscle mass in this study, whereas resistance training did. It is possible that NES protocol (1 h daily, pulse rate 40 Hz, pulse width 0.25 ms, stimulations for 10 s followed by 20 s of rest), was not optimized in this study (unfortunately, a dose-finding preliminary study was not performed). Maire et al. showed an improvement in impairment and function due to an arm-interval exercise program with an arm ergometer. Notably, lower limbs were not involved in this exercise program, thus avoiding any potential adverse events at the operated hip, and the patients were able to obtain a relevant change in VO2 peak value just exercising with an arm ergometer for 30-minute sessions three times a week. Again, it is impressive that beneficial effects persisted at a 1-year follow-up. Overall, data from these three RCTs supported the role of treadmill training with partial body weight support, resistance training of the quadriceps muscle, and the use of an arm ergometer. Neumuscular electrical stimulation may be used in those patients who cannot perform resistance training. Notably, all three interventions were evaluated in addition to “standard” rehabilitation, although “standard” rehabilitation itself varied across studies, as it varies in clinical practice from institution to institution and even within the same center. It is surprising that these three interventions, i.e., the only ones supported by RCTs, seem not to be routinely included in the most frequently used rehabilitation protocols.

The fifth study we reviewed showed that early intensive rehabilitation accelerated the attainment of functional milestones leading to shorter length of stay
in hospital and reduced economic burden. Notably, early intensive treatment begun on day III postoperatively was well tolerated and patients, who were at high risk, exhibited no complications and a good compliance. The message from this study is relevant. However, generalizability of the results is questionable because setting change (patients in the intervention group were early transferred to the rehabilitation ward) may be a crucial confounder. Furthermore, the authors did not fully describe the exercise protocols. Duration and frequency of treatment sessions were the only variables described in detail, provided that exercise types were the same in intervention groups and controls. The last limitation further reduces generalizability of the conclusions.

Interventions performed during the late postoperative phase (operation interval > 8 weeks)

Two of the 4 studies we reviewed adopted a control group with no training. In one further study, patients in the control group were only invited to walk. The absence of an “active” treatment in the control group seems to reflect the lack of a general belief on the usefulness of rehabilitation during the late post-operative phase. This is consistent with the lack of definite exercise protocols specifically designed for the late phase. All the three studies showed beneficial effects due to the combination of active range of motion exercises, low resistance strengthening exercises, and weight-bearing exercises with hip-abductor eccentric strengthening. Benefits included improvements in muscle strength, walking speed, and function as measured by an ordinal scale. Functional gains seem to depend on muscle strength augmentation, because improvements in function mirrored strength increases. Jan et al. showed that the exercise program performed in the intervention group actually increased muscle strength of hip flexors, extensors and abductors. Sashika et al. and Unlu et al. showed a significant increase in the strength of hip abductors. Notably, patients in all the three studies performed low-resistance exercises without progressive resistance increase. We can hypothesize that higher intensity and progressive resistance enhancement could generate greater strengthening effects in these subjects and greater functional gains, but data on effectiveness (and safety) is not available to support our hypothesis. In the study by Jan et al, patients in the intervention group also performed walking exercise (30 minutes daily at a comfortable speed). This possibly contributed to both strength increase and functional improvement, but the absence of a group performing only walking exercise makes impossible to drive definitive conclusions on walking role which is further confounded by spontaneous walking by patients belonging to both groups. Moreover, it is unlikely that walking itself exerted a relevant effect, because of two observations. Firstly, in the study by Unlu et al. controls were invited to walk (although intensity, duration and frequency were not defined) and they showed an outcome significantly worse than patients in the intervention group who performed a combination of active range of motion exercises, low resistance strengthening exercises, and weight-bearing exercises with hip-abductor eccentric strengthening. Secondly, patients in the intervention group in the studies by Jan et al, and Sashika et al., obtained significant improvements in strength and function without including walking in their exercise programs. In the study by Unlu et al. difference in age among the groups at baseline may be a potent confounder. However, the oldest patients were those who performed the exercise under physiotherapist supervision, whose outcome results were the best. So, a relevant role of age as a confounder in this study seems unlikely. The fourth study was based on the comparison between two “active” groups. Trudelle-Jackson et al. showed the superior effect of weight bearing exercises versus active range of motion and low-resistance training exercises. Benefits included increases in muscle strength and postural balance. Self-perceived functional ability significantly increased in the weight-bearing group only, although difference between the two groups did not achieve statistical significance. The authors concluded that weight bearing exercise was the effective treatment. Unfortunately, the exercise program performed by the controls did not increase muscle strength, as shown by the authors. So, this study simply confirms that changes in function mirrored changes in muscle strength (strength did not increase in the controls who did not improve functionally, whereas it significantly increased in the treatment group that obtained a significant functional gain). We conclude that the specific exercise regimen adopted by the control group was not effective as for muscle strength. This may depend on the lack of weight-bearing exercises, as suggested by the authors, but it may also depend on inadequate exercise dosage.
In agreement with a putative crucial role exerted by weight bearing exercises, in the oldest study by Sashika et al., the addiction of weight bearing exercises to range of motion and low-resistance strengthening exercises showed a trend toward a greater increase in muscle strength.

Overall data from late-phase postoperative studies support the usefulness of rehabilitation, in agreement with the well known persistence of both impairment and functional limitations, and with the effectiveness of physical exercise in the management of hip osteoarthritis in chronic patients who do not undergo surgery. Furthermore, they emphasize the importance of weight-bearing exercises that may be the crucial component of the exercise programs. Compliance is expected to play a crucial role in affecting the results of each exercise program, as suggested in the study by Jan et al.

Limitations of the studies reviewed and recommendations for further research

Overall, a limited number of controlled studies was found. Sample size was modest (it ranged from 14 to 80 subjects). No multicenter studies were found. These three limitations are quite surprising, given the huge number of patients who undergo THA, the high request for rehabilitation and the economic burden of both rehabilitation and long-lasting disability. It is mandatory that multicenter clinical trials with large sample sizes become available to optimize physical exercise programs after THA. Patients included in the controlled trials were selected, mainly to avoid comorbidities and/or postsurgery complications. This may limit generalizability of the results (indeed, this is a general problem for clinical trials). Specific trials should be performed for homogeneous subgroups of patients with relevant comorbidities (such as neurologic diseases, rheumatoid arthritis, diabetes, arterial diseases) or complications (such as nerve injuries, length difference between lower limbs, recurrent dislocations) that may affect the effectiveness of rehabilitation and need specific interventions. Further potential sources of variability not investigated were arthroplasty type and surgical approach. New studies should take into account these sources of variability by either selecting homogeneous patients as for type of prosthesis and surgical operation, or stratifying participants for these variables in adequately powered trials. In most cases, the outcomes were measured at the body level of the International Classification of Functioning, Disability and Health. Furthermore, outcome assessments were not homogeneous across studies. In future research, outcome measures should include indexes of both activity and participation, and an effort should be made to use the same validated scales. "Standard" rehabilitation varied across studies. These differences mirror discrepancies among rehabilitation protocols from various institutions throughout the world. Efforts should be made to minimize differences in standard rehabilitation by preferring interventions whose effectiveness was supported by previous controlled trials.

Limitations of the study

Articles from journals not indexed in Medline were not searched for, so as articles written in a language other than English. A single reviewer performed the first-line analysis of the literature. We focused on postoperative exercise programmes, i.e., a single component of rehabilitation in patients with THA. To build an evidence-based rehabilitation protocol, several other issues should be addressed, including pre- and post-operative education, preoperative exercises, optimal setting to perform rehabilitation, weight-bearing and range-of-motion restrictions, sport activity, treatment both of comorbidities and complications, and pain management.

Conclusions

Three main suggestions emerge from this review of controlled trials on the effectiveness of physical exercise programs after THA: early postoperative protocols should include additive interventions whose effectiveness has been shown (i.e., treadmill training with partial body-weight support, unilateral resistance training of the quadriceps muscle, and arm-interval exercise program with an arm ergometer). Late postoperative programs are useful and should comprise weight-bearing exercises with hip-abductor eccentric strengthening.

References

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