Post-Rehabilitation Exercise Considerations Following Hip Arthroplasty

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Lead Summary:

Joint replacement (arthroplasty) is the mainstay of surgical interventions for individuals with pain and impairments of the hip that have been recalcitrant to conservative interventions. Management of clients who have had a hip arthroplasty (HA) can be challenging for the strength and conditioning professional given the potential for late complications and residual impairments. Although common overarching principles exist that may improve the client's fitness level, a requisite understanding of surgical approaches, precautions, rehabilitation principles, as well as residual impairments are necessary to design safe and effective post-rehabilitation exercise programs. This manuscript provides a framework for post-rehabilitation program design following HA.

Key words: Hip, Joint replacement, Rehabilitation, Special populations, Surgery

Introduction and Epidemiology

Joint replacement (arthroplasty) is a viable surgical option for individuals with pain or impairments of the hip that have been recalcitrant to conservative measures. According to the American Academy of Orthopaedic Surgeons approximately 230,000 joint replacement procedures of the hip were performed in the United States in 2008 (1, 34). Owing to successful outcomes and increased survivorship of modern prosthetic implants, a projected increase to 572,000 procedures by 2030 has been reported (32).

While there are numerous types of joint replacement procedures described in the literature, each approach shares a common goal of replacing the native joint with a prosthetic implant. Indications for joint replacement, referred to hereafter as hip arthroplasty (HA), are multifactorial and range from disease and degenerative pathology to fractures and developmental disorders (42, 57). Osteoarthritis in particular has been implicated as the underlying pathology leading to joint replacement in more than 85% of persons in the United States Medicare population, with avascular necrosis and rheumatoid arthritis occupying the second and third positions respectively (5).

The purpose of this article is to provide the strength and conditioning professional with an overview of both the perioperative and post-rehabilitation needs of patients and clients who have had a HA surgery. A discussion grounded in the available evidence will be used to provide a framework for post-rehabilitation exercise program design following HA. Progression and advancement of post-rehabilitation program variables will be highlighted within the context of safety and consensus.

Surgical Technique and Implications

Numerous surgical techniques (conventional versus minimally invasive) as well as implant designs for performing HA have been described in the literature Irrespective of technique and implant selection, HA procedures have been reported as efficacious for improving quality of life to the recipient (8, 34). Moreover, ninety percent of patients report being satisfied with their improvements at 15-years following surgery and a majority of surgeons surveyed allow patients to return to previously performed low to moderate impact activities in 3-6 months (27, 57).

From a procedural perspective, factors such as method of implant fixation (cemented vs. non-cemented) and anatomical approach (location and level of invasiveness) have relevance in the early stages of rehabilitation. In particular, individuals who have cemented implant fixation of the prosthesis are generally allowed to weight-bear as tolerated immediately following surgery, whereas it is common for surgeons to restrict weight bearing for a period of up to 6-weeks in those who have a non-cemented implant (53). An advantage to having non-cemented fixation is thought to be longevity of the procedure (as there is no risk of loading induced cement failure), thus it is more commonly encountered in a relatively younger population (53, 67).

Of particular importance to everyone involved in the care of the patient following HA is the surgeons "approach" to the procedure. The intervention, residual impairments, risk for revision, and precautions are often dependent on the type of surgical approach. Specifically, whether the procedure was performed from an "anterior," "anterolateral," 'lateral" or posterolateral" surgical approach must be considered. Although various surgical procedures have been practiced over the past decade and regional discrepancies exist, the posterolateral approach is most common as it is preferred by many due to excellent joint exposure during the procedure

(16, 69). Although the posterolateral approach is most common, minimally invasive techniques such as the direct anterior approach (referred to as anterior approach hereafter) are gaining popularity and preferred my many surgeons trained in the technique (18, 37). The posterolateral and anterior approach have similar goals of restoring joint function; however there are considerable procedural differences that have direct relevance in terms of immediate post-operative and long-term precautions. While it is beyond the scope of this manuscript to discuss the various types of implants and detailed surgical procedures, a brief discussion of the conventional posterolateral and anterior approaches will provide the framework for understanding the associated impairments, precautions and post rehabilitation recommendations.

The conventional posterolateral approach is performed through an incision that may extend up to 20 centimeters (10) in the posterior and lateral region of the hip (Figure 1). Posterior approaches with smaller incisions have been described in the literature; however, a recent meta-analysis concluded that the minimally invasive posterior was not superior to the traditional approach in regard to postoperative hip function and recovery (36). The conventional procedure has been associated with positive outcomes in function and pain; however a high rate of post-operative dislocation has been documented when compared to other techniques such as the anterior approach (12, 15, 18, 56, 69). While there are variations to the posterolateral approach it is common practice for the surgeon to split or partially release the gluteal maximus and release the short hip external rotators (piriformis, superior and inferior gemelli, quadratus femoris, and obturator internus) as well as the hip capsule (15, 16, 69) to gain access to the joint. Once the joint is exposed the surgeon will then dislocate the hip by simultaneously placing the leg in flexion, internal rotation and adduction (16). Once dislocated the joint is prepared and the prosthetic implants are inserted. The decision to use a cemented vs. non-cemented implant is

dependent on the patient needs. Non-cemented implants are generally reserved for the younger more active patient (53, 67) as the procedure omits the risk of component loosening, cement fracture, and premature revision surgery. Lastly, the surgeon will repair the soft tissue, with a complete repair offering greater levels of stability (15, 16, 69). As expected the soft tissue requires time to heal and may render the hip unstable until it is adequately healed with sufficient strength and power (15, 16, 21).

The anterior approach (Figure 2) is minimally invasive and performed through a small anterior incision (less than 10 centimeters) between the tensor fasciae latae and sartorius muscle (47). This procedure is rather new compared to the posterolateral, lateral and anterolateral approaches and is reported to be less invasive but more technically demanding on the surgeon (44). An advantage of this technique lies in the surgical procedure as the hip muscles are not disrupted (cut or released) during surgery (18, 44), thus the hip has a reduced incidence of instability and weakness when compared to more invasive procedures such as the posterolateral approach.

Post-Surgical Rehabilitation and Discharge Criteria

Physical therapists are the primary rehabilitation providers throughout the perioperative and post-operative stages of care following a HA. Physical therapists integrate a patient care model where they independently examine, evaluate, posit a prognosis, and provide interventions in an attempt to optimize outcomes following these procedures (3). Physical therapists must recognize that surgeons often have strict requirements (protocols) that their patients must follow post-surgery, and must remain aware of these requirements when determining their interventions.

The rehabilitation process for a patient following HA may begin well before their date of surgery with pre-operative education. Pre-operative education often serves the primary purpose of ensuring patient and family understanding of the precautions that must be adhered to following surgery. Pre-operative instruction in the anticipated post-surgical exercise regimen may also be provided. The patient may also be counseled in pre-operative exercise for general conditioning and/or weight loss.

Post-operative rehabilitation is generally initiated in the first 24 hours following surgery (53). The immediate goals of rehabilitation in the acute care hospital are targeted at the patient's safety and begin with patient and caregiver education in precautions and contraindications specific to the surgical procedure (see "Precautions" section).

A majority of patients will be on anticoagulant medications following HA. Anticoagulant therapy serves as a means of ameliorating the effects of immobility and the resultant hypercoagulable state following surgery, all of which may promote a deep vein thrombosis (DVT) and potentially a pulmonary embolism (PE) (28). Although the optimal duration of how long a patient will be taking anticoagulant medications may vary, evidence suggests that extended out-of-hospital prophylaxis may continue for up to one month and potentially longer as a means of preventing complications (24). While there are known benefits to anticoagulation therapy for reducing complications, all of the individuals involved in the patient's care must recognize that potential risks such as bleeding, infection and thrombocytopenia may develop (24, 52).

Exercise interventions begin immediately following surgery and are targeted at encouraging motion to further decrease the likelihood of DVT and other perils associated with immobility following surgery (PE, pneumonia, lasting effects of general anesthesia). The

physical therapist will begin other range of motion activities to assist in reduction of localized edema (53). Targeted strengthening exercise of other areas of the body may also be indicated for some persons based on impairments and would be included in the physical therapy plan of care. Patients are assisted out of the hospital bed and begin gait training (walking) with an appropriate assistive device that will maintain patient safety yet provide the least restriction to the patient in ambulation. It should be noted that interventions to address balance as well as fall risk are included at this stage (3). The inpatient (acute-care) rehabilitation generally continues daily until the patient is medically stable and capable to be discharged to a lower level of medical care. At this early point in the rehabilitation process goals are centered on the patient demonstrating safety with mobility, improving ability to get in and out of bed, decreased fall risk, and compliance with the prescribed exercise regimen.

At the next appropriate lower level of care (generally outpatient or home health care rehabilitation), the physical therapy program is continued with additional exercise and load for strengthening, when appropriate. Patient education continues to ensure that all post-surgical precautions are followed and that the patient is not at risk for a fall. The ability independently to lift the operative leg (especially as needed to get in and out of bed) continues to be an important goal. Generally, the need for the skilled intervention of a physical therapist ends when the patient is deemed to be safe in mobility (with or without an assistive device), independent in performing their exercise program, and able to maintain all precautions during activities. It is at this point where the patient is independent from a medical standpoint, but may still gain benefit from continued exercise-based interventions (with appropriate advancements) guided by a strength and conditioning professional.

Post-Rehabilitation Coordination of Care

Although physical therapists technically provide the rehabilitation care for individuals as long as they continue to have functional limitations related to the initial illness, injury or surgery, these professionals are often limited in their ability to guide a patient to complete recovery for various reasons. In this instance the physical therapist will counsel the patient and encourage that they pursue activities that will further improve their function and quality of life. Patients at this stage are often faced with the challenge of bridging activities from a regimented, healthcare professional driven rehabilitation process to a self-guided program. The transition to an independent program may be quite daunting to the patient who is unfamiliar with the principles of safe and effective exercise. The patient perceived chasm to an unsupervised exercise regime provides an opportunity for the strength and conditioning specialist familiar with HA to provide a bridge of relief to these individuals. In this model, an open line of communication between physical therapist and strength and conditioning specialist may allow every patient to realize their maximum physical potential following successful HA**.** It is the experience of the authors that strength and conditioning specialists are often limited by the information provided to them by their clients. Thus communication between providers is a critical requirement in the effort to optimize safe and effective long-term outcomes for each patient following HA. Moreover, the authors recommend that all individuals who have had a HA procedure also receive clearance from their surgeon prior to beginning any post-rehabilitation exercise program.

Post-Rehabilitation Exercise Considerations

Residual Impairments

A working knowledge of the most likely residual impairments and precautions should provide the framework for post-rehabilitation program design of clients following HA. From an impairment perspective a body of evidence suggests that clients who have had the anterior approach will progress to higher functional levels early in their rehabilitation, however, by the time of discharge from formal (physical therapy) care there are minimal differences in function (44, 51). At the time of discharge and extending well into the next few years or longer clients having had both procedures will typically have impairments; however the degree of impairments is multifactorial and is often dependent upon the pre-morbid status of the client, comorbidities, and type of procedure as more invasive procedures are associated with greater muscle morbidity (9, 45, 54, 55, 57).

When considering function following HA, evidence suggests that up to two years following HA patients will demonstrate limitations in their ability to climb stairs, and present with decreased walking velocity as well as reduced step length (33, 38). By one-year following surgery only 32 percent of persons will utilize an assistive device for ambulation, and by the 5th postoperative year this usage further declines to 13 percent (57). While the aforementioned evidence points to deficits persisting up to 2-years it should be recognized that this is the terminal point of the investigations and that functional limitations may persist well beyond 2-years. Thus, it is imperative that all individuals involved in the care of individuals following HA be cognizant of the potential safety ramifications (i.e. fall risk) associated with these functional limitations.

From an impairment perspective, a loss of hip extension and external rotation range of motion (17, 33, 50, 51) has been frequently identified among patients following HA. These limitations may affect normal walking mechanics as well as ability to perform functional

activities such as placing ones foot on their opposite knee for donning and doffing shoes and socks or performing foot hygiene activities. It should be noted that a loss of flexion range of motion has not been identified following HA, and any activity exceeding ninety degrees of flexion should be avoided in most cases among those individuals who have had a posterolateral approach (see precautions section).

Muscle morbidity is most often reported as a persistent problem following HA with more invasive procedures leading to greater damage (45). One investigation using magnetic resonance imaging identified muscle morbidity (atrophy or decreased radiological density) of the iliopsoas, gluteus maximus, and hip adductor/abductor groups for up to 2-years following HA(54). Moreover, reports of reduced power and strength of the hip flexors, abductors, adductors, and external rotator musculature have been reported well beyond discharge from rehabilitation (17, 51, 55, 60). Finally, decreased postural stability of the operative leg (63), and reduced cardiovascular fitness (23) have also been reported as persistent impairments following HA.

Evidence in the form of investigations extending beyond the discharge phase suggests the persistence of numerous impairments and functional limitations. While many studies have investigated deficits up to 2-years, there is evidence that deficits in activities such as walking may continue to persist beyond this timeframe (57). Moreover, there is evidence that a time-dependent gradual decline in function begins on average, approximately 5-years after HA (57) further substantiating the need for continued and progressive exercise-based interventions.

Precautions

Formal rehabilitation programs often include periods of post-operative protection or avoidance of specific motions or strengthening exercises, and over the course of rehabilitation

these restrictions are gradually lifted (48). However, some restrictions or precautions remain well beyond discharge. Strength and conditioning specialists involved in designing post-rehabilitation programs need to identify and follow these precautions (48). Specifically, the strength and conditioning specialist should remain cognizant of the client's increased proclivity for dislocation as well as the need to restrict activities that may influence premature wear of the prosthetic components.

Dislocation: Dislocation comprises the second most common complication following HA and occurs in up to 11 percent of individuals following a primary or revision HA (41, 42, 70). A cumulative report of 14 studies found an average dislocation incidence of 3 percent following a primary posterolateral approach when the soft tissue was adequately repaired versus 4 percent with minimal repair (41). The risk of dislocation is up to 6 times more likely following a posterolateral approach than an anterior approach (15, 41). This difference in risk of dislocation is likely the result of the more invasive nature of the posterolateral approach as soft tissue (muscle and capsule) is dissected to gain entry into the joint. Approximately 50% of all dislocations will occur during the first 3-months postoperatively (8, 42) and are thought to be caused by instability ensuing from weakness of the repaired hip musculature (gluteal and external rotators) as well as noncompliance with post-operative activity precautions. Generally speaking, post-operative activity restrictions are physiologically derived from an understanding of the surgical approach and are generally consistent among surgeons although the duration of these restrictions having variability. Specifically, the hip is dislocated during surgery (posterolateral approach) by combined flexion, internal rotation and adduction, (Figure 3) thus performance of these motions (combined or individually) following surgery may place an individual at risk for dislocation (46, 53, 62). Moreover, activities such as flexing the hip past 90

degrees such as (Figures 4A, B) assuming the position similar to sitting in a low chair or squat position are purported causes of hip dislocation following a posterolateral approach HA(15, 46). Outside of activity restrictions there is evidence that an increased body mass index, alcoholism, having a previous dislocation, and undergoing a HA for repair of a fracture are additional risk factors for a dislocation following HA (9, 15).

Although a majority of dislocations occur during the first 3-months evidence suggests that dislocations may occur well-beyond 5 years following HA (66). In light of the aforementioned evidence, it is recommended that clients be instructed to avoid individual and combined motions of hip flexion greater than 90 degrees, adduction past midline (other leg) and internal rotation (Figures 3) following posterolateral approach HA for an undetermined time period. Moreover, clients should be instructed to avoid any activities such as squatting and kneeling that places their hip in a position of greater than 90 degrees flexion (Figure 4B). Lastly, evidence suggests that those individuals who possess greater amounts of flexion, adduction and internal rotation mobility are more likely to experience a dislocation (31) which further substantiates our recommendation to avoid efforts to increase these motions for an undetermined time period following a posterolateral approach HA.

Contrary to the posterolateral approach, evidence exists to suggest that there is a substantially decreased risk of dislocation following the anterior approach. In fact, evidence has suggested that post-operative mobility restrictions are generally unnecessary following an anterior approach (49, 56). Specifically, investigations have reported no change in the dislocation risk when precautions were not implemented following an anterior approach (49, 56).

Component Wear and Loosening: Contradictory evidence exists as to specifically defined risk factors that influence component failure (loosening) and wear. Generally, component failure and wear occur in a linear pattern with time since surgery, with up to 10 percent of individuals having loosening by year 10 and increasing 17 percent by year 14 (57). It is accepted that wear is a function of loading, thus the number of cycles (repetitions) and magnitude of loading (body mass) will influence the amount of wear (27). Post-operatively, strength and conditioning professionals must recognize that there is a balance between the amount of activity needed for cardiovascular health and general fitness levels and the amount of activity that might lead to premature wear or failure of the prosthesis (27). Many surgeons advise their patients to avoid high level activity following HA to prevent premature wear and loosening of the prosthetic implants (57) as an association between activity levels and component failure has been substantiated (57). A consensus of what constitutes "high activity" has been established among representative members of the hip society. While the details of recommended activities will be discussed in the exercise programming section of this manuscript, it should be noted that high impact activities are best avoided (57). The patient's physical therapist or surgeon can be a valuable resource for obtaining information related to specific precautions; however, privacy regulations may prevent their discussion of patient records. When inquiring with healthcare providers about a previous or current patient, a discussion in generalities related to precautions for procedure types may be required rather than discussing restrictions of a particular patient.

Exercise Programming

Individualized exercise programs have been found to be effective in improving both early- and late-phase impairment and physical function after HA (13). There is convincing

evidence that both aerobic and strength-based training promote favorable adaptations following HA, although it is not clear whether a combination of the two produce synergistic effects (13). Supporting evidence for benefits of flexibility exercise following a HA procedure are currently lacking, however a theoretical basis does exist for its inclusion in a targeted fitness routine. The following section provides evidence-based guidelines for these 3 pillars of fitness in the post-rehabilitation phase following a HA procedure.

Resistance Training

Resistance training is arguably the most important component of a post-rehabilitation HA exercise program. Strengthening of muscle and connective tissue at the hip joint is critical to restoring normal physical function following surgery (13). Provided proper guidelines are followed, resistance training is both safe and effective in helping these individuals achieve functional recovery and enhancing their quality of life.

Theory suggests that it is beneficial to initiate a progressive resistance training program as expeditiously as possible following surgery since muscle strength declines as much as 4% per day during the first week of immobilization(2). Given the potential for impaired muscle performance early resistance training is imperative provided it respects physiological healing and is balanced with appropriate medical management. A randomized, controlled study by Husby et al.(25) identified considerable benefits associated with such an approach. Twenty-four early-stage (1 week post-surgical) subjects were randomized into either a low-resistance therapy group or a group that supplemented conventional therapy with heavy strength training. The experimental group performed 4 sets of 5 repetitions of both the angled leg press and hip abduction with resistance bands. Training was carried out at ~85% of 1 repetition maximum

(RM), with loads progressively increased to accommodate ongoing increases in strength. Sets were separated by 2 minute rest periods. At the conclusion of the 4 week study, subjects that supplemented therapy with resistance training showed significantly greater lower body strength and rate of force development compared to those who received therapy alone. Moreover, work efficiency was significantly greater in the strength trained group versus a control group at a 6 and 12-month follow-up (by 29% and 30%, respective) (26). Importantly, no adverse effects were associated with heavy resistance training. These findings are consistent with those of Suetta et al.(61), who found that early-stage progressive resistance exercise increased maximal lower body strength, muscle mass, and muscle function to a greater extent than standard rehabilitation in elderly subjects, as well as markedly reducing their length of hospital stay.

Resistance exercise is equally important and effective for enhancing functional abilities in later-stage post-HA recovery. Hauer et al.(20) reported that a 3-month progressive resistance training program significantly increased strength, functional motor performance, and balance while reducing behavioral and emotional problems related to falls in a group of subjects who had a HA performed 6 to 8 weeks prior. A control group showed no changes in these parameters. Similarly, Trudelle-Jackson and Smith(64) found significant improvements in self-perceived function, muscle strength, and postural stability following an 8-week strength training intervention in subjects 4 to 12 months post-HA versus no change among subjects who received active range of motion and low resistance isometric exercise. No training-related injuries were reported in either study.

Multi-joint lower body movements should form the basis of resistance-based exercise programming for individuals in the post-rehabilitation stage following HA. Exercises such as squats, lunges, and leg presses are safe (provided range of motion precautions are adhered to)

and effective choices that target large amounts of muscle important to physical function. Given that hip torque and hip flexion increase in tandem with maximal torque occurring near the bottom phase (maximum flexion of hip and knee) of movement (59), the joint is most vulnerable in this lower range. Thus, range of motion in these exercises should be restricted to no more than 90-degrees of hip flexion to help to ensure that stresses do not exceed the capacity of the joint, which could potentially result in a hip dislocation (25). Care should be exercised when performing lunges or squats to avoid concurrent hip internal rotation or adduction past the midline of the body in clients with traditional dislocation precautions.

It also is beneficial to include abduction and external rotator exercises as part of post rehabilitation HA programs. The hip abductors are essential for normal gait and prevention of falls (25), thus exercise that directly targets these muscles can help to restore normal physical function among individuals following HA. When the goal is to target the hip abductors, exercises performed in the frontal plane (0-degrees of hip flexion) are preferable to those performed in the transverse plane (i.e. 90-degrees of flexion) as the latter changes the mechanical advantage so that the external rotators dominate over the abductors (14) and may theoretically place the hip in simultaneous flexion, adduction and internal rotation predisposing the individual to a dislocation. Standing abduction can be performed with cables, bands, machines, and/or ankle weights to optimize a training effect. Strengthening of the external rotators is important for hip stability as well as performance. Evidence suggests that these muscles may be impaired following HA as a result of surgical dissection despite a successful repair. Specific exercise such as the “clam or clamshell” (Figures 5A, B) may be utilized to target the external rotators and gluteal musculature. Advancement may be achieved by adding resistance bands around the knees or by adding a cuff weight proximal to the knee.

Progressive overload is a basic tenet of strength-based training (4) and this principle applies when designing a resistance program for the client post HA. Although it has been shown that high-intensity strength training is a viable strategy in early-stage recovery (25), it may be too strenuous for some individuals with additional comorbidities or low baseline fitness levels. Moreover, some clients may still be taking anticoagulant medications which may increase their risk of bleeding (24, 28) in response to more strenuous exercise. A more conservative approach starting out at 50% 1RM and then gradually increasing intensity to 80% after 6 to 8 weeks has proven both safe and effective among individuals having had a HA(61). The authors recommend obtaining a 5-10RM and using a conversion formula or estimation table (4) to determine the 1RM. Two to four sets per exercise performed 2 to 3 days per week is a general recommendation for volume and frequency, although variables must be adjusted based on the abilities of the individual. Since maximizing strength is a primary goal, rest intervals should average 2 to 3 minutes between sets to ensure that loading is not substantially compromised (71).

Cardiorespiratory Exercise

Many individuals who undergo HA have experienced physical disability and reduced activity levels for years, causing them to become aerobically deconditioned (68). Direct cardiorespiratory exercise therefore can be beneficial in helping these individuals regain aerobic capacity and endurance, and improving quality of life. Given the principle of specificity, gait-based training has particular applicability in restoring normal ambulation and thus functional capabilities in the client following HA.

Studies directly evaluating exercise-related cardiovascular changes are limited. Hesse et al.(22) showed significant functional improvements following treadmill training with partial

body weight support provided as a supplement to physical therapy for subjects in early-phase recovery post HA. Subjects were evaluated by the Harris Hip Questionnaire, an assessment instrument consisting of weighted scores for pain, limping, the use of aids for mobility, maximum walking distance, competence in daily activities, and hip range of motion. After 10 days, the Harris Hip score in those receiving physical therapy plus partial body weight supported treadmill training was more than 13 points higher (a positive finding) compared to controls receiving physical therapy alone. Further, clinically relevant improvements persisted at a 3 and 12 month follow-up. It should be noted that 1 subject in the training group previously diagnosed with a DVT expired (died) from a pulmonary PE, likely as a result of the strenuous exercise dislodging a preexisting thrombus. Moreover, evidence suggests that PE is one of the more common causes of death following joint replacement surgery (52). This emphasizes the need to judiciously reserve vigorous aerobic training only for those clients that are medically cleared for such activity.

As a general rule, intermediate slow distance cardiorespiratory exercise for the lower body is preferable during the initial 8 weeks post-surgery. An intensity of 40-60% heart rate reserve is a good starting point for most individuals, with progressive increases gradually employed over time. After the first few months, more vigorous cardiorespiratory exercise such as interval training may be beneficial for enhancing aerobic capacity. Duration in the early stages will depend on initial cardiorespiratory fitness level, but the goal should be to accumulate approximately 20-30 minutes of moderate aerobic activity per day. Those who are highly deconditioned might only be able to tolerate 5-10 minutes of activity at a time and thus should perform multiple shorter daily aerobic bouts. More fit individuals can generally perform the

entire 20-30 minutes consecutively if desired. A high frequency of aerobic training is desirable to facilitate early-stage recovery, with exercise carried out most if not all days of the week.

Arm exercise also can be employed to help restore cardiovascular function. Given that this form of training can be performed more vigorously than leg-based exercise in the early stages of recovery, it may have particular benefit during this time as a means for promoting greater enhancements in cardiorespiratory fitness. Maire et al.(40) demonstrated significant improvements in VO_2 max following a 6-week arm ergometry interval-training compared to a non-training control group that received traditional daily rehabilitation. In addition, trained subjects covered significantly greater distances in the timed 6-minute-walk-test versus controls (405 m versus 259 m, respectively). One-year follow-up showed the training group maintained this advantage as well as displaying significantly lower scores on the Western Ontario and McMaster Universities Osteoarthritis Index (indicative of a better outcome)(39).

Flexibility Exercise

Restoring functional range of motion may be a goal if mobility impairments persist following HA. Therefore, targeted flexibility training would theoretically seem beneficial in these individuals. Evidence exists to suggest that persistent hip extension and external rotation mobility deficits may persist following HA (17, 50, 51). Moreover, contracture of the iliopsoas, rectus femoris, adductors and tensor fasciae latae have been identified among patients reporting hip pain at the two-month time period following HA(6). In the aforementioned descriptive study(6), the authors reported successfully managing 92 percent these individuals with a flexibility program that consisted of manual stretching during clinic visits 2-5 times a week, and a home exercise program. Several studies have shown positive effects on physical function when

flexibility training was performed as part of a general fitness program that included targeted strengthening exercise (29, 58, 65). However, none of these studies evaluated the effects of stretching independently, making it impossible to determine whether results were additive, neutral or perhaps even inhibitory on outcome measures. Trudelle-Jackson et al.(64)found strength training to be more effective than range of motion exercise in all reported measures of self-perceived function, muscle strength, and postural stability among individuals who had a HA procedure. While this indicates that strength training is more critical than flexibility training for functional outcomes post-HA, it does not provide insight as to whether stretching-based exercise might enhance results when performed in combination with resistance exercise. Some studies have shown that resistance training increases joint-related flexibility to a similar extent as static stretching provided that lifting is carried out over a full range of motion (43), however this was not determined in the population with a HA. Interestingly, a non-randomized study of elderly individuals following a HA reported no improvements in hip range of motion following a non-supervised, at-home flexibility and strengthening protocol (58). Given the home-based nature of this study, it could be postulated that the null results were likely due to suboptimal exercise performance and/or poor compliance with the routine.

The dearth of studies examining flexibility exercise in following HA makes it difficult to provide evidence-based recommendations for this fitness component. There would seem to be little downside to performing slow, static stretching exercise for the hip joint to improve impaired motions and logic dictates that it may help to enhance functional movement(19). Ideally, flexibility exercise may be performed in all 3 cardinal planes (respecting aforementioned range of motion precautions), taking the stretches to the point of mild discomfort and holding the position for approximately 10 seconds (7). Several sets should be performed in each plane

separated by 10-15 second rest intervals. In healthy individuals a 3-day-a-week flexibility routine has been shown to be equally effective for increasing hip range of motion as daily stretching providing that stretches are carried out twice a day (11). As a general precaution, individuals who have had a posterolateral approach arthroplasty should avoid stretches that involve combined flexion, adduction and internal rotation (Figure 3) as it may predispose the joint to dislocation and potentially stress healing tissue if performed prematurely. There is preliminary evidence that flexibility-based exercise such as Pilates may have benefit post-HA (35), although further investigation is necessary to draw more definitive conclusions. Other techniques designed to improve mobility such as dynamic stretching and proprioceptive neuromuscular facilitation have not been adequately assessed to determine safety and effectiveness in this population.

Return to Recreational Sports and Exercise

Increased postoperative activity levels following HA undoubtedly will contribute to improved strength, power, endurance as well as cardiovascular fitness. While these health benefits are well-known, high level activity participation is not without risk as prosthetic wear and component loosening are directly related to activity. While there are numerous factors that may contribute to failure, loosening and wear of the prosthetic components is undoubtedly related to loading magnitude and frequency (27).

Strength and conditioning professionals involved in the prescription of exercise following HA must recognize that there is a balance between the level of activity needed for the pursuit of fitness and the amount that may predispose a client to prosthetic failure as a result of premature wear (27). Although there is a paucity of evidence-based guidelines for return to sports and higher level activities, a consensus of experts in a 2007 survey of the Hip Society and the American Association of Hip and Knee Surgeons recommended a return to recreational athletic

activity 3-6 months after surgery (30). Specific guidelines from the aforementioned consensus report suggest that over 90% of those surveyed agree that with experience golf, swimming, doubles tennis, hiking, road cycling, dancing, bowling, low-impact aerobics as well as training with treadmill, weight-machines, elliptical machine and stationary bike are acceptable activities (21, 27). Moreover, it is recommended that a gradual return to familiar activities specific to each individual's needs and desires should be considered. Activities such as jogging, martial arts, singles tennis, contact sports, moderate to high impact aerobics, snowboarding, racquetball or squash, baseball and softball were not recommended by over 50% of those surgeons surveyed(21, 27). Despite consensus based guidelines it is advised that the individual client consult with their team of health care providers (primary care physician, surgeon, and physical therapist) prior to resuming higher level sport or exercise.

Conclusion

Joint replacement surgery is a common surgical procedure and its incidence is likely to increase over the coming years with advancements in prosthetic design that meet the demands of the younger more active patient. Those who have undergone HA often require extensive rehabilitation to restore normal physical function post-operatively. Although formal physical therapy has been identified as an efficacious means of restoring independence with functional activities and quality of life, strength and mobility impairments may persist well-beyond discharge from formal medical care. Following discharge from formal physical therapy, many individuals may benefit from guided exercise prescription well into the post-rehabilitation stage.

With this opportunity identified, strength and conditioning professionals are well positioned to play a key role in the post-rehabilitation stage, however, to protect the safety of

each person they must first acquire knowledge of relevant physical limitations and potential precautions/contraindications to exercise. Clear communication with the physical therapist and surgeon is instrumental for determining relevant post-operative limitations and precautions. As a general rule, a combination of resistance training and cardiovascular activity is beneficial in facilitating optimal recovery. A focus on strengthening the hip musculature and connective tissue is paramount in this regard, as well as to help prevent future dislocation of the reconstructed joint. Although a paucity of research has investigated the efficacy of flexibility exercises following HA it is not unreasonable to address mobility deficits on an as needed basis within the constraints of mobility precautions. A conservative approach is best, with a gradual progression of program variables implemented over time, based on individual response to training.

Figure Legends

Figure 1: Hip incision location for a posterolateral approach.

Figure 2: Hip incision location for a direct anterior approach

Figure 3: Combined position of hip flexion greater than 90 degrees with adduction past midline and internal rotation during lower extremity stretch. Position is contraindicated following a posterolateral approach to hip arthroplasty as it may lead to a dislocation.

Figure 4: Flexion of the hip greater than 90 degrees which is a precaution following a posterolateral approach hip arthroplasty procedure, A. Flexion of the hip greater than 90 degrees while seated B. Flexion of the hip greater than 90 degrees during a squat activity

Figure 5: Illustration of clamshell exercise used to strengthen the external rotator musculature. **A:** Individual lies on their non-surgical side with knees bent to approximately 45-80 degrees. **B:** Once in position the individual raises superior (top) knee toward ceiling while keeping feet together.

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