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Recommendations in the rehabilitation of patients undergoing hip abductor tendon repair: a systematic literature search and evidence based rehabilitation protocol

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Abstract

Introduction Advanced hip imaging and surgical findings have demonstrated that a common cause of greater trochanteric pain syndrome (GTPS) is hip abductor tendon (HAT) tears. Traditionally, these patients have been managed non-operatively, often with temporary pain relief. More recently, there has been an increase in published work presenting the results of surgical intervention. A variety of open and endoscopic transtendinous, transosseous and/or bone anchored suture surgical techniques have been reported, with and without the use of tendon augmentation for repair reinforcement. While patient outcomes have demonstrated improvements in pain, symptoms and function, post-operative rehabilitation guidelines are often vague and underreported, providing no guidance to therapists.

Materials and methods A systematic search of the literature was initially undertaken to identify published clinical studies on patients undergoing HAT repair, over a 3-year period up until May 2020. Following the application of strict inclusion and exclusion criteria, studies were identified and the detail relevant to rehabilitation was synthesized and presented. Published detail was combined with the authors clinical experience, with a detailed overview of rehabilitation proposed for this patient cohort.

Results A total of 17 studies were included, reporting varied detail on components of rehabilitation including post-operative weight bearing (WB) restrictions, the initiation of passive/active hip range of motion (ROM) and resistance exercises. A detailed rehabilitation guide is proposed.

Conclusion In combining the current published literature on rehabilitation after HAT repair and our own clinical experience in the surgical management and post-operative rehabilitation of these patients, we present an evidence-based, structured rehabilitation protocol to better assist surgeons and therapists in treating these patients. This rehabilitation protocol has been implemented for several years through our institutions with encouraging published clinical outcomes.

Keywords Hip abductor tendon tears · Gluteal tendons · Rehabilitation · Surgery · Patient outcomes

Introduction

Greater trochanteric pain syndrome (GTPS) is a term used to define the condition of greater and peri-trochanteric hip pain and tenderness [1, 2]. Advanced imaging and surgical findings has revealed a common cause to be hip abductor tendinopathy and tears [3–5]. Conservative measures can be effective, with a systematic review published in 2017 identifying corticosteroid injections, shockwave therapy and exercise as providing benefit [6]. Two recent high-quality studies provided further support for advice (patient education) and exercise [7, 8]. However, neither study identified rates of hip abductor tendon (HAT) tears versus tendinopathy. Nonetheless, a high symptom recurrence

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rate is demonstrated following conservative treatment [9], with patients frequently undergoing multiple courses of non-operative treatment [10]. Studies investigating imaging findings in patients with recalcitrant GTPS have demonstrated HAT tears in 46–88% of cases [1, 3].

While several clinical HAT studies have been published over the past 3 years [11–27], detail provided on post-operative rehabilitation within these studies remains limited. This provides little direction to the therapist working with these patients in their post-operative management. Ideally, a post-operative rehabilitation protocol will be safe, individualized and provide quality patient education to ensure optimal patient recovery. Therefore, a good understanding of provocative postures and movements, and a sound knowledge of a range of exercises that will progressively load the hip abductor mechanism and address underlying biomechanical issues that may predispose to pain and pathology is important.

This manuscript reviews the more recent published literature [11–27] and associated content provided pertaining to rehabilitation following surgical HAT repair and, combined with the authors' published clinical experience working with these patients, a rehabilitation protocol is presented providing therapists a more structured resource. While the proposed protocol should be modified as required based on individual patient characteristics, together with the nature (i.e. augmented versus non-augmented HAT repair) and quality of the repair, this protocol has been successfully implemented for several years through our institution(s) with encouraging patient outcomes.

Incidence of HAT tears and patient presentation

GTPS (including HAT tears) is common in patients presenting with hip issues in primary care [9]. In a retrospective database imaging study of 185 pelvic magnetic resonance imaging (MRI) scans, 30–50% of those over 50 years of age demonstrated a HAT tear, albeit no clinical patient information was provided [28]. More recently, Oehler et al. [29] reported that the presence of partial and full thickness HAT tears were more frequently detected on 3.0 T versus 1.5 T MRI scanners and, therefore, should HAT tears be suspected in symptomatic patients a 3.0 T MRI system should be considered. Females presenting with GTPS out number males by a ratio of approximately 4:1 [9, 30] and out number males by a ratio of 10:1 for HAT repairs [31]. Alpaugh et al. [31] suggested that female pelvic geometry may create forces that further irritate the gluteal tendons as they wrap around the greater trochanter, while Fearon et al. [32] reported that a lower femoral neck-shaft angle and greater trochanter girth, often observed in women, are associated with GTPS. HAT tears can result from a specific trauma [33–35], although the majority of patients report an insidious onset of pain/symptoms [36, 37], thought to be precipitated by early tendinopathy, partial and eventually full thickness tearing [38]. Finally, patients following total hip arthroplasty (THA) may develop symptomatic HAT pathology, particularly if undertaken via a transgluteal surgical approach, with Pfirrmann et al. [39] reporting that 56% of patients with trochanteric pain and abductor weakness after THA demonstrated HAT defects on MRI. HAT surgical repair has been undertaken in patients with THA [26, 27], with comparable outcomes to those undergoing isolated HAT repair [27].

Patients with HAT tears report lateral hip and thigh pain [40], together with pain on lateral hip pressure and sleeping on the affected side [40]. The pain and disability reported are similar to (or worse than) those with end-stage hip osteoarthritis (OA) [40]. Pain and/or difficulty when standing on the affected limb is commonly reported [40], and patients with symptomatic HAT tears may demonstrate hip range of motion (ROM) and abduction strength asymmetry [40]. These complaints, together with known provocative postures, positions and movements, provide the treating clinician with insight into appropriate patient education and management.

Surgical HAT repair methods

While HAT repair was traditionally performed through an open approach providing enhanced visualization, combined with ease in preparation of bone surfaces and fixation, the first endoscopic series was reported in 2009 [41]. Now, both open and endoscopic techniques are commonly described, with systematic reviews reporting no difference in post-operative clinical scores albeit a higher complication rate with open repair techniques that may include infection/hematoma, deep vein thrombosis (DVT) an re-tear [31, 42]. However, the repair technique employed is generally dependent on the nature and size of the tear [12, 16, 17, 23, 26, 31, 43, 44], with studies over the past few years increasingly reporting the use of augmentation devices to assist the surgical repair [11, 13, 14, 18, 24, 45–48].

Theoretically, an endoscopic approach reduces soft tissue trauma and results in a smaller wound(s). However, through our institution(s), open repairs (augmented and non-augmented) are generally employed. Nonetheless, the surgical process is similar and requires elevation of the tendon off the bony footprint, debridement of the torn tendon ends in preparation for formal repair, and bone decortication in preparation for reattachment. Excision of the trochanteric bursa and any enthesophytes that are present is performed. Various iliotibial band (ITB) procedures have been reported, including "Z" lengthening [49] and making an "ITB window" [38]. The authors suggested that while the biomechanical effect of ITB disruption (with a potential deleterious effect on abductor function) is unknown, a potential benefit may be the decompression of the trochanter and tendon footprint [38]. Interestingly, an earlier finite-element modeling study reported a hip centralizing/stabilizing effect provided by the iliotibial tract [50] and, therefore, further research may be required to ascertain the true outcome of a concomitant ITB procedure.

A variety of reattachment methods have been employed, with the use of suture anchors and/or bone tunnels commonly reported across more recently published clinical HAT repair studies [11–27]. There appears to be no consensus on reporting the size of tears or the best technique to address these. Davies et al. [51] reported the use of suture anchors for smaller tears with minimal retraction, and the use of transosseous fixation through paired tunnels for larger tears. Other authors reported using single or double row repairs [23, 27], with one study reporting that small/medium tears (< 2 cm) were repaired in a single row fashion while large/massive tears (> 2 cm) were repaired in a double-row suture bridge fashion [23]. Another study reported using double row repairs specifically for full thickness tears [17]. Both transtendinous and suture bridge repair methods are reported, which may be indicated for either partial or full (or nearly full) thickness tears, respectively [12, 44].

A range of augmentation devices have been employed over the past few years including the Ligament Augmentation and Reconstruction System (LARS, Corin Group, Cirencester, UK) [11, 13, 24], an acellular human dermal matrix (Graft Jacket, Wright Medical Technology, Arlington, TN; Allopatch HD, Conmed Linvatec, Largo, FL; ArthroFlex, LifeNet Health, Virginia Beach, VA) [45, 47, 48] or fresh-frozen Achilles tendon allograft [48], a non-resorbable collagen patch (Zimmer, Winterthur, Switzerland) [14], a platelet-rich fibrin matrix [16] and other bioinductive implants (Rotation Medical, Plymouth, MN; Regeneten, Smith & Nephew) [46]. More recently, Zhu et al. [52] demonstrated in a sheep model that in the chronic or delayed HAT repair setting, altered healing at the bone-tendon interface with significantly inferior biomechanical properties is observed, compared with an acute tear and repair. This may provide further rationale for these augmented HAT repair methods. Currently, there are no published studies comparing augmented and non-augmented repairs.

Published literature on the rehabilitation of patients following HAT repair

Search strategy

A search was conducted on the 1st of May 2020 for articles that addressed the surgical management and/or rehabilitation of patients with HAT tears. Titles, abstracts and keywords (Scopus), title and abstract (CINAHL), topic and Web of Science category (Web of Science), topic (Medline via Web of Science) and the Cochrane Library were searched with no date restriction (Table 1). Only studies reporting clinical outcomes (on at least one patient) and within 3 years of the review were included to ensure the relevant information presented was current, with study inclusion and exclusion criteria are listed in Table 2. Figure 1 demonstrates the flow of studies included and excluded in the current review.

After removing duplicates, 1,325 articles were Title and Abstract screened by JE and AF, and any disagreement was resolved by discussion. Following this, 160 papers were full text screened. Four additional papers were identified from reference lists of the review papers and book chapters located initially, leaving 17 papers for data extraction. Detail on the rehabilitation content outlined for each of the studies included in the final review was presented (Table 3). The

Table 1 Search terms in MEDLINE database

Search Term	
1	TS = (gtps OR "Greater Trochanteric Pain Syndrome" OR "Gluteus medius tendinopathy" OR "Gluteus medius tendonitis" OR "Gluteus medius tendinitis" OR "Gluteus medius tendinosis" OR "Gluteus medius tenosynovitis" OR "gluteus medius tear*" OR "gluteus medius avul*" OR "gluteus medius rupture" OR "gluteus medius" OR "Gluteus minimus tendinopathy" OR "Gluteus minimus tendinitis" OR "Gluteus minimus tendonitis" OR "Gluteus minimus tendinosis" OR "Gluteus minimus tenosynovitis" OR "gluteus minimus rupture" OR "gluteus minimus" OR "gluteus minimus tear*" OR "gluteus minimus avul*" OR "gluteal tendon" OR "gluteus minuimus" OR "Gluteal tendinopathy" OR "Gluteal tendonitis" OR "Gluteal tendinitis" OR "Gluteal tendinosis" OR "Gluteal tenosynovitis" OR "gluteal tear*" OR "Trochanteric Bursitis" OR "hip abductor*" OR (hip AND "abductor avul*") OR (hip AND "abductor tendon"))
2	TS = (surgery OR endoscopy OR repair OR reconstruction OR sutures OR transosseous)
3	#2 AND #1

Level of Evidence of each clinical study included was provided (Table 3), though a detailed methodological quality assessment tool was not employed given the study sought to investigate and synthesize the rehabilitation content provided within each study, rather than the patient clinical outcomes.

Summary of published rehabilitation content

In brief, the primary rehabilitation components reported across the included studies included post-operative weight bearing (WB) restrictions, the initiation of passive/active hip ROM and resistance exercises (together with restrictions imposed). Of the 17 clinical HAT repair studies included in

Table 2 Criteria for study inclusion and exclusion. Reviews and book chapters were included in the full text screening process so as to permit hand searching of reference lists

Inclusion criteria	Exclusion criteria
HAT or gluteal medius or minimus tendon repair studies, with or without hip arthroplasty surgery (within 3 years of the review (i.e. May 2017 to May 2020)	Surgical Technique papers without any clinical patient outcomes provided
Any surgical approach	Articles that were solely about imaging findings (descriptive or reliability & validity, or other)
Full-text articles	Articles that were solely about histological findings
In English	Hip intra-articular studies (e.g. ligamentum teres and labral tears)
Systematic review	Conference abstracts (poster or podium)
Narrative review	Tendon transfers (e.g. gluteal maximus transfer)
Book chapter	Tendon ‘replacement’ procedures (e.g. Achilles allograft)

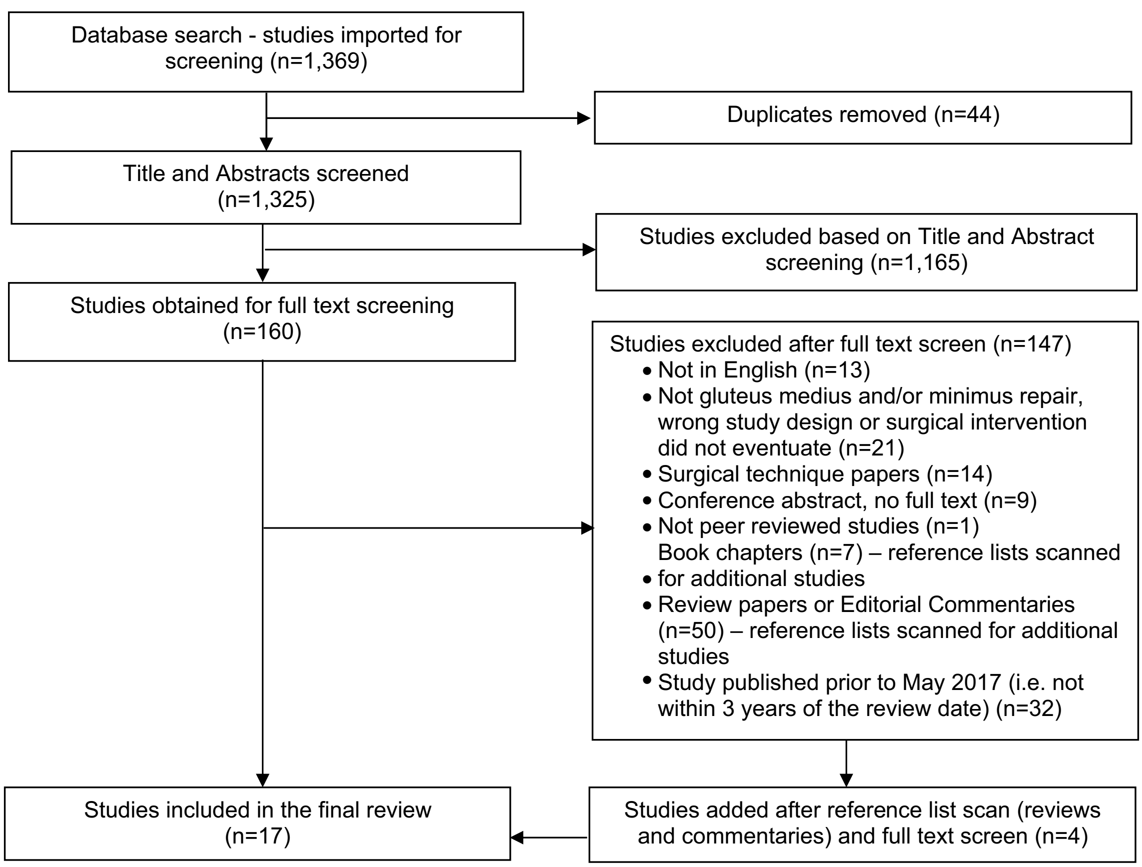

Fig. 1 Flowchart of studies included and excluded in the current review

Table 3 Rehabilitation detail outlined in studies (chronological order) reporting outcomes after surgical hip abductor tendon (HAT) repair

Author(s)	Year	Level of evidence	Surgical technique	Patient sample	Reported rehabilitation, activity and/or movement restrictions
Huxtable et al. [11]	2017	IV	Open repair augmented with LARS through a transosseous tunnel, with suture anchors	21 patients Mean age 62.1 years (range, 44–78)	Coordinated programme of graduated WB and progressive exercise over at least 6 months (detailed rehabilitation regimen provided in text)
Perets et al. [12]	2017	IV	Tran-tendinous (partial thickness tears) or suture bridge (full or near full thickness) repair using suture anchors, with concomitant arthroscopy for labral tears	14 patients Mean age 57.4 years (range, 46–74)	Partial WB (20 lb) and use of a hip abduction brace for 6 (partial thickness tears) or 8 (full thickness tears) weeks, with avoidance of hip abduction, adduction, internal rotation and external rotation throughout this time. Completion of 3–4 months of physical therapy to gain strength and ROM. No specific exercises outlined
Ebert et al. [13]	2018	IV	Open repair augmented with LARS through a transosseous tunnel, with suture anchors	110 patients Mean age 63.2 years (range, 43–82)	Coordinated programme of graduated WB and progressive exercise over at least 12 weeks, with ongoing exercise education and advice until 12 months (detailed rehabilitation regimen provided in text)
Fink et al. [14]	2018	IV	Open repair with transosseous fixation and a non-resorbable collagen patch	30 patients Mean age 76.8 years (range, 68–83)	Partial WB with 10 kg for 6 weeks, followed by a progressive increase in WB until 3 months. Avoidance of active hip abduction for 6 weeks. No specific exercises outlined
Hartigan et al. [15]	2018	IV	Trans-tendinous endoscopic repair	25 patients Mean age 53.5 years (range, 38–70)	Partial WB (20 lb) and use of a hip abduction brace for 6 weeks, with avoidance of active hip abduction and internal rotation, as well as passive adduction and external rotation, throughout this time. Gentle strengthening initiated at 6 weeks, with a total of 3–4 months of physical therapy. No specific exercises outlined
Saltzman et al. [16]	2018	III	Open or endoscopic repair using suture anchors, with or without the addition of platelet-rich fibrin matrix	18 patients with (mean age 60.3 years, range 46–74) and 29 patients without (mean age 63.1 years, range 38–89) fibrin matrix	3-phase protocol including: 1) Phase 1 (0–6 weeks), partial WB with a walker or crutches and full-time bracing, gentle passive ROM, 2) Phase 2 (6–12 weeks), progression to full WB, discontinuation of bracing, initiation of hip strengthening exercises, and 3) Phase 3 (> 12 weeks), ambulation without assistance and return as tolerated to general activity. No specific exercises outlined
Thaunat et al. [17]	2018	IV	Tran-tendinous endoscopic (partial thickness tears) or double-row suture bridge (full thickness) repair	20 patients Mean age 66 years (range, 45–82)	Non WB for 6 weeks with an abduction brace, with avoidance of passive lateral rotation, passive adduction, active internal rotation and active abduction. Restricted hip flexion to 90° for 3 weeks. No specific exercises outlined

Table 3 (continued)

Author(s)	Year	Level of evidence	Surgical technique	Patient sample	Reported rehabilitation, activity and/or movement restrictions
Ebert et al. [18]	2019	IV	Open repair augmented with LARS through a transosseous tunnel, with suture anchors	56 patients Mean age 65.8 years (range, 51–84)	Coordinated rehabilitation program of graduated WB and progressive exercise over 3–4 months, with ongoing advice and exercise prescription provided as required. No specific exercises outlined
DeFroda et al. [19]	2019	IV	Mini-open double row repair with suture anchors	31 patients Mean age 59 years (SD, 9.0)	None reported
Godshaw et al. [20]	2019	IV	Endoscopic repair using suture anchors	1 patient (78 years)	WB as tolerated with hip abduction brace. Physical therapy initiated from day 5, with active abduction and strengthening avoided for 6 weeks. Hip strengthening initiated from 6 weeks. No specific exercises outlined
Lau et al. [21]	2019	IV	Endoscopic repair using suture anchors	7 patients Mean age unknown given mixed surgical cohort reported	Crutches and a hip abduction brace for 6 weeks, avoidance of hip abduction exercises for 12 weeks
Okoroha et al. [22]	2019	IV	Endoscopic repair using suture anchors	60 patients Mean age 57.9 years (SD, 9.9)	Partial WB with crutches (or a walker) with an abduction brace for 6 weeks. Progression toward full WB, no brace and initiation of strengthening exercises between 6–12 weeks
Saltzman et al. [23]	2019	IV	Open or endoscopic repair using suture anchors	38 patients Mean age 60.5 years (SD, 10.3)	Partial WB with crutches (or a walker) with an abduction brace for 6 weeks. Progression toward full WB, no brace and initiation of strengthening exercises within 6–12 weeks
Ebert et al. [24]	2020	IV	Open repair augmented with LARS through a transosseous tunnel, with suture anchors	142 patients Mean age 64.3 years (range, 43–84)	Initial partial WB with crutches, with full WB permitted from 6–8 weeks. Out-patient exercise rehabilitation initiated from 2–4 weeks, including hydrotherapy and land-based exercises. Specific structured exercises prescribed from 2–4 weeks, stationary cycling from 4–6 weeks, functional WB exercises prior to 8 weeks and resisted hip abduction exercises from 8 weeks. Ongoing exercise education and advice until 12 months. Detailed rehabilitation regimen cited in text [13]
Fox et al. [25]	2020	IV	Open repair through a transosseous tunnel, with suture anchors	165 hips Mean age at follow-up 69 years (range, 34–91)	Non-WB for 6 weeks and discouragement of active hip abduction, followed by WB as tolerated. Walking encouraged for rehabilitation no other specific exercises outlined
Maslaris et al. [26]	2020	IV	Open or endoscopic repair using suture anchors	45 patients (12 with prior THA) Mean age 65.8 years (SD, 9.2)	None reported

Table 3 (continued)

Author(s)	Year	Level of evidence	Surgical technique	Patient sample	Reported rehabilitation, activity and/or movement restrictions
Ratnayake et al. [27]	2020	IV	Open repair with bony tunnels or suture anchors	44 patients (17 with and 27 without THA) Mean age 63 years (SD, 10–12)	WB as tolerated, physical therapy with crutch or walker ambulation for 4 weeks and restriction from active hip abduction for 4 weeks

BW body weight, *WB* weight bearing, *ROM* range of motion, *THA* Total Hip Arthroplasty

the final review, two [19, 26] failed to include any information on rehabilitation (Table 3).

A progressive increase toward full WB was generally not permitted until at least 6–8 weeks [11, 13, 16, 22–24]. Some studies indicated specific restrictions (i.e. 10 kg, 20 lb, flat foot or touch WB) or non WB (or limb avoidance) for 6–8 weeks [12, 14–17]. Others stated that post-operative WB was permitted as tolerated [20, 27], without any indication of when patients successfully transitioned to full WB. Some studies were less descriptive and mentioned ‘protected’, ‘restricted’ or ‘partial’ WB with no indication of a specific restriction and/or WB graduation [21–23]. Two studies specifically outlined a graduated increase toward full WB, including that by Ebert et al. [13] and Huxtable et al. [11] (< 20% BW at 1–2 weeks, 50% BW to 4 weeks and full WB from 6 weeks).

Some studies reported the initiation of passive and/or active ROM exercises within the first (or from) 6 weeks [11, 13, 16, 22, 23]. Various hip ROM restrictions were advocated within the first 3–6 post-operative weeks, including restrictions on hip flexion ˃90° [11, 13, 17], avoidance of hip adduction beyond the midline [11–13, 15, 17] and avoidance of passive hip external rotation [12, 15, 17] and active hip internal rotation (and/or internal rotation beyond the midline) [11–13, 15, 17]. Hip abduction braces were employed in less than 50% of the included clinical studies, for a duration ranging from 6–12 weeks post-surgery [12, 15–17, 20–23].

The initiation of resisted exercises varied and were reported to begin from 2–12 weeks post-surgery [11, 13, 15, 16, 20, 22–24]. Variation across studies was observed in the initiation (or avoidance) of active hip abduction, including from 4 weeks [27], 6 weeks [14, 15, 17, 20], 8 weeks [11, 13, 24],and 12 weeks [21]. Only one study reported on the initiation of sport-specific activities from 3–6 months [13], while two studies provided a more detailed rehabilitation progression (including specific exercises) to be undertaken throughout the post-operative timeline [11, 13]. Otherwise, current published literature failed to provide any detail to the therapist on the types of ROM and/or resistance exercises undertaken by patients.

Principles of rehabilitation following HAT repair

To return the patient to an optimal level of pain-free function, the therapist must assist in managing post-operative pain, swelling and inflammation, restoring hip ROM, progressively increasing trunk, pelvic and lower limb strength, and improving functional performance. As the age of patients in published surgical outcome studies ranges from 33 to 89 years [53], rehabilitation requires an individualized progressive programme to address the specific needs of the patient. Irrespective of age, patients often present with a long duration of symptoms and functional disability [40] and, in addition to the early conservative post-operative period required for repair protection, progressive post-surgical physical conditioning is critical.

While we are yet to ascertain the association between patient outcome and factors such as age, body mass index (BMI) and gender, length of pre-operative symptoms, severity of condition (i.e. tear size, involvement of gluteus minimus and/or medius, presence and severity of bursitis, degree of pre-operative muscular fatty atrophy, revision surgery etc.), physical conditioning and any associated co-morbidities, adjunct surgical procedures and biomechanical contributing factors, these must still be considered. Conflicting evidence exists about the association between pre-operative pain, function and pathology on post-operative outcome, with Bogunovic et al. [54] reporting a strong correlation between pre-operative gluteal fatty infiltration and worse pain and satisfaction after HAT repair. Albeit via a different (and augmented) surgical technique, a more recent study reported no such associations [55].

Furthermore, HAT repair may be undertaken concomitantly with THA or hip arthroscopy (i.e. osteochondroplasty, labral and/or cartilage repair), and this may promote deviation in the proposed program based on specific contraindications relative to the concomitant surgery. Therefore, any adjunct surgical procedures will require modification of the rehabilitation program according to which surgery has the highest risk of disruption and concomitant contraindications.

HAT repair rehabilitation guidelines

Given the aforementioned systematic literature search and synthesis of the more recently published literature outlining the rehabilitation of patients after HAT repair, combined with the extensive clinical experience of the authors, a summary of patient goals, education and exercise prescription, as well as the recommended progression of ROM and WB restrictions throughout the presented seven phase rehabilitation program is provided in Table 4. It should be noted here that while this rehabilitation guide has been developed given the existing published detail on HAT repair rehabilitation, it remains an untested rehabilitation algorithm despite it being successfully employed for some time in clinical practice by the authors, with encouraging published clinical outcomes in patients following the proposed regimen. However, given the lack of any evidence-based rehabilitation studies after HAT repair, together with no published rehabilitation guides on the topic to assist the surgeon and rehabilitation team, this guide will serve as an important first step in future research.

While Phase 2 (1–2 weeks post-surgery) is a time-based rehabilitation phase, Phases 3–5 are all time- and criterion-based. The timeline provided for Phases 6–7 serve as a guideline for patient expectations and intended exercise prescription, with progression throughout these later stages largely criterion based. While the nominated goals should be met in each phase prior to initiation of the next, should a patient exceed expectations early in the phase, caution must be taken in accelerating a patient too aggressively at risk of jeopardizing the early surgical repair. Furthermore, while the authors' experience has been biased toward open (augmented and non-augmented) surgical repair methods, we would not be so inclined to accelerate these protocols should endoscopic (and potentially less invasive) methods be employed, given the underlying nature of the tendon-bone healing interface that remains the same irrespective of the surgical method employed.

Phase 1: Pre-operative counseling and exercise prescription

The pre-operative education and conditioning of patients are critical in preparing them both physically and mentally for surgery and the lengthy post-operative rehabilitation process. At the very least, patients should be educated on the post-operative demands, as well as the goals and expectations of them throughout the stepwise rehabilitation program. Education and teaching of proficient ambulation and negotiation of stairs using two forearm crutches should be incorporated. In addition, educating the patient on how certain pre- and post-operative postures/movements may act to exacerbate their pre-operative pain and adversely overload their early post-operative repair is important. In particular, it has been suggested that excessive hip flexion (such as sitting for prolonged periods in a low chair) may increase ITB tension, and subsequently compression of the abductor tendons [56–58]. Furthermore, increased compression of the abductor tendons by the iliotibial tract has been demonstrated with increasing hip adduction angle [59], so activities such as crossing the legs should be avoided, while education on good lower limb alignment (avoiding hip adduction and knee valgus) during WB activities should be provided [56].

Exercises to improve pre-operative strength and fitness should be encouraged. These should prepare patients for surgery and provide familiarization to the likely post-operative exercises. Improving upper limb and trunk strength is beneficial for early post-operative bed/chair transfers and crutch ambulation. Educating the patient on options to improve cardiovascular fitness, that do not aggravate their condition, may permit a faster recovery from surgery, while reducing BW and the associated additional loading borne by the hip abductor mechanism. In the authors' clinical experience and current practice, a direct and immediate referral of

Table 4 The proposed phases of pre- and post-operative management in patients undergoing hip abductor tendon (HAT) repair, outlining estimated timeframes, specific goals, weight bearing (WB) graduation, hip range of motion (ROM) and exercise prescription

Phase (estimated timeframe)	Phase goals	WB and hip ROM restrictions	Patient education and exercise prescription
Phase 1 (Pre-surgery)	1. Patient education on surgical procedure, safe post-operative ambulatory requirements and contraindicated postures/ movements 2. Physical preparation of the patient and introduction of early post-operative exercises	N/A	• Upper limb/trunk exercises to assist post-operative bed/chair transfers and crutch ambulation • Education on dietary intake and safe cardiovascular exercise options to encourage weight reduction and a faster surgical recovery • Education on provocative positions (excessive hip flexion, internal rotation and adduction), as well as how these may compromise integrity of the early surgical repair • Exercise prescription individualized for the patient, dictated by pain, symptoms and specific presentation (both for physical preparation though also to ensure the patient is familiar with the early post-operative exercises that will be undertaken)
Phase 2 (0–2 weeks)	1. Reduce post-operative pain and oedema 2. Avoid excessive WB (> 20% BW) 3. Avoid provocative postures and positions that may adversely stretch/load the repair site 4. Maintain lower limb joint mobility, muscle tone and circulation	• WB: ≤ 20% of BW with 2 forearm crutches • ROM: passive and active-assisted 'comfortable' hip ROM (avoidance of hip flexion > 90°, adduction beyond the midline and internal rotation)	• Educate on strategies to reduce pain/inflammation (including analgesic medication and cryotherapy) • Education and practice in proficient heel–toe PWB ambulation • Reinforce the need to avoid provocative postures and positions that may adversely stretch/load the repair site • Passive and active-assisted hip ROM exercises within a pain-free ROM • Active ankle dorsi- and plantar-flexion exercises • Isometric contraction of the quadriceps, hamstrings, adductor and gluteal musculature • Terminal range knee extension
Phase 3 (2–4 weeks)	1. Pain and oedema well managed 2. Proficient heel-toe gait at 50% BW with 1–2 crutches 3. Proficiency in undertaking home-exercise program	• WB: ≤ 20% BW (1–2 weeks) to 50% BW (4 weeks), with 1–2 forearm crutches • ROM: as per Phase 2 • Avoidance of resisted hip abduction, extension and internal rotation in flexion	• Continue Phase 2 exercises • Education on quality of gait, particularly with the progression toward a single forearm crutch • Introduce gentle stretching of the hip flexors • Introduce additional home-based exercises, such as: prone knee flexion, multi-plane isometric hip adduction, bilateral supine bridging, resisted knee flexion, heel raises, standing weight shift activities and standing hip extension • Introduce hydrotherapy, including: deep water walking (forwards, backwards, sideways), heel raises, mini squats, straight leg hip flexion and extension, cycling, modified scissor kicks • Remedial massage and tissue mobilisation as required • Please note: graduation in WB and exercise should be based upon the assumed healing of the surgical repair, as well as the individuals' surgical details, pain response and tolerance to load, lower limb strength/function, and other musculoskeletal (i.e. knee, lower back) or health issues

Table 4 (continued)

Phase (estimated timeframe)	Phase goals	WB and hip ROM restrictions	Patient education and exercise prescription
Phase 4 (4–8 weeks)	1. Pain-free gait and full WB as tolerated from 8 weeks* (1 crutch permitted for protection, stability and/or safety as required) 2. Pain-free during low demand daily tasks 3. Proficiency in performing Phase 4 home-based exercises 4. Near full and comfortable hip ROM ($\geq$ 80% hip ROM in all planes compared to the contralateral hip) * full WB and resistance work may be delayed in direct repair situations	• WB: 50% BW (4 weeks) to full WB as tolerated from 6 weeks, with 1 forearm crutch as required • ROM: Progress toward full pain-free passive and active hip ROM	• Continue Phase 2 and 3 exercises • Education on improving quality of gait as required • Increase demand of home-based exercises, including: isometric and isotonic external hip rotation (using theraband), prone hip extension, supine hip flexion, bilateral supine bridging (with isometric abduction using theraband) and standing hip abduction and extension • Introduce WB functional exercises/activities as tolerated, including: bilateral wall and free-standing squats (with assistance if required), step exercises, single leg stance balance and weight shift activities • Introduce stationary cycling (week 4–6) and gentle freestyle swimming for hip ROM and/or fitness • Hydrotherapy: continue Phase 3 exercises, plus shallow water walking (waist depth), straight leg hip abduction and circumduction, deep squats, step ups/downs, lunges, single leg balance and proprioception exercises
Phase 5 (8–12 weeks)	1. Pain-free and full active hip ROM ($\geq$ 90% hip ROM in all planes compared to contralateral hip) 2. Pain-free six-minute walk test without the use of walking aids (gait speed patient dependent) 3. Ability to single leg stand for 15–30 s, with VAS $\leq$ 3/10 4. Proficiency in performing home- and clinic-based exercises for the independent continuation of post-discharge rehabilitation	• WB: full WB as tolerated, with a crutch/cane for stability as required • ROM: as per Phase 4	• Continue Phase 3 and 4 exercises • Further education on quality of gait and undertaking functional activities (i.e. stairs, rising from sitting, etc.) as required • Increase demand of home-based WB and non-WB exercises, including: trunk flexion and core stability activities, quadruped 4-point kneel) exercises with hip extension, standing resisted (theraband) hip extension and abduction, side-lying hip abduction and variation in single leg stance (with proprioceptive focus), varied step and lunge-orientated exercises • Continue Phase 3 and 4 hydrotherapy exercises
Phase 6 (3–6 months)	1. Normal, pain-free unaided gait 2. Hip abductor strength $\geq$ 90% using MMT and/or HHD, compared with contralateral limb 3. Comfort in ambulating stairs (ascent and descent) and gradients 4. Ability to single leg stand for 15–30 s, with VAS $\leq$ 1–2/10 5. Return to work (dependent on occupational demands) 6. Proficiency in performing all full WB strengthening, functional and proprioception activities	• WB: full WB, no crutches • ROM: full and pain-free active hip ROM	• Continue Phase 4 and 5 exercises • Education and exercises pertinent to the training of daily activities for the individual patient is required • End range stretching and soft tissue therapy of surrounding hip musculature, including (though not limited to): gluteus medius, minimus, hip flexors, iliotibial band and tensor fascia lata • Increase demand of home-based exercises, including: single limb supine bridge exercise, side and prone bridging, pelvic hitching, lateral band side steps (crab walks) and other varied WB activities • Outdoor road cycling is permitted, and rowing ergometry and elliptical trainers can be introduced • Phase 3 and 4 hydrotherapy exercises can be ceased upon initiation of a more functional land-based program

Table 4 (continued)

Phase (estimated timeframe)	Phase goals	WB and hip ROM restrictions	Patient education and exercise prescription
Phase 7 (6–24 months)	1. Ability to tolerate pain-free walking distances of any length/duration 2. Hip abductor strength ≥ 95% using MMT and/or HHD, compared with contralateral limb 3. Ability to perform all activities of daily living pain-free 4. Ability to effectively negotiate uneven terrain and soft sand 5. Return to pre-operative low-impact recreational activities and/or sport as required	• WB: full WB, no crutches • ROM: full and pain-free active hip ROM	• Continuation of Phase 4–6 strengthening and functional WB exercises as required, with a focus on exercise technique and appropriate lower limb alignment • Exercises employed should begin to replicate what is required for the patient's individual activity goals, which may include sport-specific activities • Ongoing education may be required in undertaking specific work, recreational and/or sporting activities, with particular reference to optimal ergonomic and/or technique modification to avoid provocative positions and/or movements that could be implicated in a recurrence of symptoms

Note, the proposed WB time frame, activity/movement restrictions and exercise progression may vary with the type of surgery, specific surgeon preferences and the patient's physical conditioning and tendon status. For example, a direct HAT repair may require longer WB and resistance training restrictions than an augmented HAT repair

ROM range of motion, *WB* weight bearing, *PWB* partial weight bearing, *BW* body weight, *VAS* Visual Analogue Pain Scale, *MMT* Manual Muscle Testing, *HHD* Hand Held Dynamometry

the patient from the orthopedic surgeon to the rehabilitation therapist is essential. This ensures that the patient is provided the time to become well educated on the aforementioned process and, dictated by the scheduled booking date for surgery, exercise prescription can also be undertaken to enhance the pre-operative conditioning of the patient prior to surgery.

Phase 2: 0–2 weeks post-surgery (including in-hospital care)

The focus of this early post-operative phase should be directed toward the adequate management of pain, swelling, inflammation and safe mobilization. First, daily DVT prophylaxis with Clexane 40 mg subcuticular injections during the in-patient stay of approximately 4 days is administered. Patients are discharged home on 100 mg of Aspirin, for two weeks. The only exception to this course is if there is a past history of a thromboembolic event or a known genetic abnormality such as Factor V Leiden deficiency. In those situations, a formal opinion from a hematologist is requested. Antibiotic prophylaxis is 2gm cephazolin at induction and a single dose 8 h post-operatively. The anesthetic is usually a general anesthetic supplemented with a block of the lateral cutaneous nerve of the thigh. Some anesthetists also use a spinal block, though this is not prescribed by the surgeon and generally determined by the anesthetist. It should be emphasized that pain medications are generally individualized. The most common regime we employ would be oxynorm 5 to 10 mg, 4 to 6 hourly for the first two days, with tapentadol 50 to 100 mg slow release for two weeks. After two days, the oxynorm is generally replaced with immediate release tapentadol 50 mg, 4–6 hourly. Paracetamol 500 mg to 1gm is given four times a day for up to several weeks. Celebrex 200 mg is also used for up to four weeks. In addition, cryotherapy (20 min at least 3–5 times daily) over the operative site is recommended, and has been shown to significantly reduce post-surgical pain by slowing nerve conduction velocity and reducing oedema [60].

As mentioned above, less than 50% of clinical HAT repair studies included in the current review have employed the use of hip abductor braces [12, 15–17, 20–23], though we have never employed these through our institutions. We acknowledge that these braces may serve a purpose in ensuring patients do not extend beyond the aforementioned ROM restrictions often employed (such as hip flexion ˃90°) and could be employed for higher risk or less compliant patients, though they are burdensome and attract a further cost to the patient. Furthermore, we have found that providing the patient is well educated on safe movements and the rationale behind doing so, they are not required and our published clinical data (low re-rupture rate, improved clinical outcomes and high patient satisfaction) [13, 24] would suggest they are not imperative, with early passive and active-assisted hip motion exercises encouraged within a pain-free ROM. However, within this early phase passive (or active) movement beyond 90° of hip flexion, neutral hip internal rotation (0°) or hip adduction beyond the midline should be avoided, due to the risk of disrupting the reconstruction and increase in compression of the abductor tendons [56–59]. Therefore, patients must be educated on avoiding provocative postures and movements that promote these contraindicated hip positions (e.g. sitting cross-legged or lying/sleeping on either side).

Early active ankle dorsi- and plantar-flexion is encouraged to maintain ankle ROM and further minimize complications such as deep vein thrombosis. Isometric contraction of the quadriceps, hamstrings, and gluteal muscles should be performed to maintain muscle tone and minimize atrophy: resisted hip abduction is contra-indicated. Finally, appropriate education, instruction and practice of safe and proficient ambulation with two forearm crutches is required, transmitting $\leq$ 20% BW through the operated limb. While several methods exist for teaching WB restrictions, we employ the use of electronic scales.

Phase 3: 2–4 weeks post-surgery

The primary goals of this phase include a well-managed pain profile, proficiency in undertaking early home-based land exercises and proficient heel-to-toe gait ambulating with 25–50% BW through the operated limb. The magnitude of early WB may be influenced by pain as well as the nature (i.e. augmented versus non-augmented) and quality of the surgical repair, whereby an augmented and/or more robust surgical repair may justify an accelerated WB and/or exercise program, hence input from the treating surgeon is paramount. Given the anticipated increase in WB, quality movement is imperative, and the progression toward one forearm crutch should only be encouraged if pain is not exacerbated, while safety and stability is not compromised. Exercises promoting lower extremity circulation, passive and active-assisted hip ROM activities, and isometric lower limb strengthening exercises should be continued. Additional exercises that may be introduced are outlined in Table 4, and include low-moderate [61] hip abductor muscular activation exercises.

Hydrotherapy can be added once wound healing is complete. While we acknowledge that hydrotherapy does not suit all patients, three studies report hydrotherapy to good effect [11, 13, 24]. In these studies, hydrotherapy has been part of a comprehensive program, and the benefit attained specifically from the hydrotherapy component cannot be deduced. Hydrotherapy may be most helpful in the earlier post-operative stages [62], particularly in those patients who are unable to undertake the desired frequency and volume of land-based exercise due to pain and apprehension, or in managing the WB status while undertaking exercises. Lower extremity WB as a percentage of BW is reported at 50.0–55.1% at the navel, 23.3–25.5% at the nipple line and 5.7–9.2% at the neck [63]. Exercises may include walking forwards, backwards and sideways, along with functional and hip ROM exercises (Table 4).

Phase 4: 4–8 weeks post-surgery

The primary goals of this phase include relatively pain-free gait and attaining full WB (with the stability of one crutch or a cane as required), $\geq$ 80% hip ROM in all planes compared to the contralateral hip and proficiency in new land-based and hydrotherapy exercises. The graduation toward full WB should be based upon the individuals' surgical details (i.e. augmented versus non-augmented, quality of fixation and repair tissue), lower limb strength/function and tolerance to exercises (pain & control), as well as the assumed maturation of the surgical repair. While evidence is scarce at both the hip and in humans, a histological study investigating the timeframe for healing of supraspinatus repairs in a primate model [64], showed that while macroscopically the repair looked healed by 8 weeks, histologically, the Sharpey fibers were not apparent in a considerable amount until 12 weeks, with bone-tendon junction healing almost, though still not mature by 15 weeks. Therefore, while we appreciate loading through the hip abductor tendons differs considerably to that at the rotator cuff, we are reluctant to advocate a return to full WB prior to 8 weeks given these aforementioned factors.

Early neuromuscular training utilizing proprioceptive WB exercises while maintaining good alignment should be initiated on the operated and non-operated limb, initiated with gentle, static, and non-complex exercises that can be easily progressed in time from double to single leg, eyes open to closed, and utilizing unstable WB surfaces. A more comprehensive series of land-based exercises is initiated (Table 4, Fig. 2), which include the introduction of strengthening exercises for the trunk, thigh and hip/pelvis (including the hip abductors), together with single leg stance and other WB activities that range from low to high [61] in hip abductor muscular activation magnitude (Table 4, Fig. 2). Three studies have advocated the use of stationary cycling following HAT repair [11, 13, 24], and we have found cycling to be well tolerated from 4 to 8 weeks. While phase 3 hydrotherapy exercises can continue and be progressed (including functional exercises such as deeper squats, lunges and stepping activities, along with single limb balance exercises), increasing the relative weight (by moving to a shallower depth) is encouraged.

Phase 5: 8–12 weeks post-surgery

Throughout this phase, the patient is working toward pain-free and normal gait that is independent of ambulatory aids. Patients should be working toward ≥ 90% hip ROM in all planes compared to the contralateral hip. They should also attain proficiency in a combination of additional land-based core stability and moderate-high [61] hip abductor activation exercises, undertaken in both WB and non WB positions (Table 4, Fig. 3). The complexity of proprioceptive WB exercises can be progressed with a focus on single leg and potentially unstable WB surfaces as tolerated. Hydrotherapy exercises can be continued if deemed appropriate. At the completion of this phase, patients should aim for a pain-free (or near pain-free) and unaided walk capacity over 5–6 min with a normalized gait pattern (at a self-selected gait speed), as well as the ability to single leg stand/balance for 15–30 s with a reported Visual Analog Pain Scale (VAS) of ≤ 3/10. During the activities of daily living the patient is engaging in, a focus on sound biomechanical alignment and loading must be stressed.

Phase 6: 3–6 months post-surgery

While patients are encouraged to continue with their progressive functional rehabilitation exercises, this phase coincides with a level of patient independence and a return to full-time work pending the occupational demands of the patient. At three months, outdoor road cycling, rowing ergometry and elliptical trainers are generally introduced. By six months, patients should be relatively pain-free

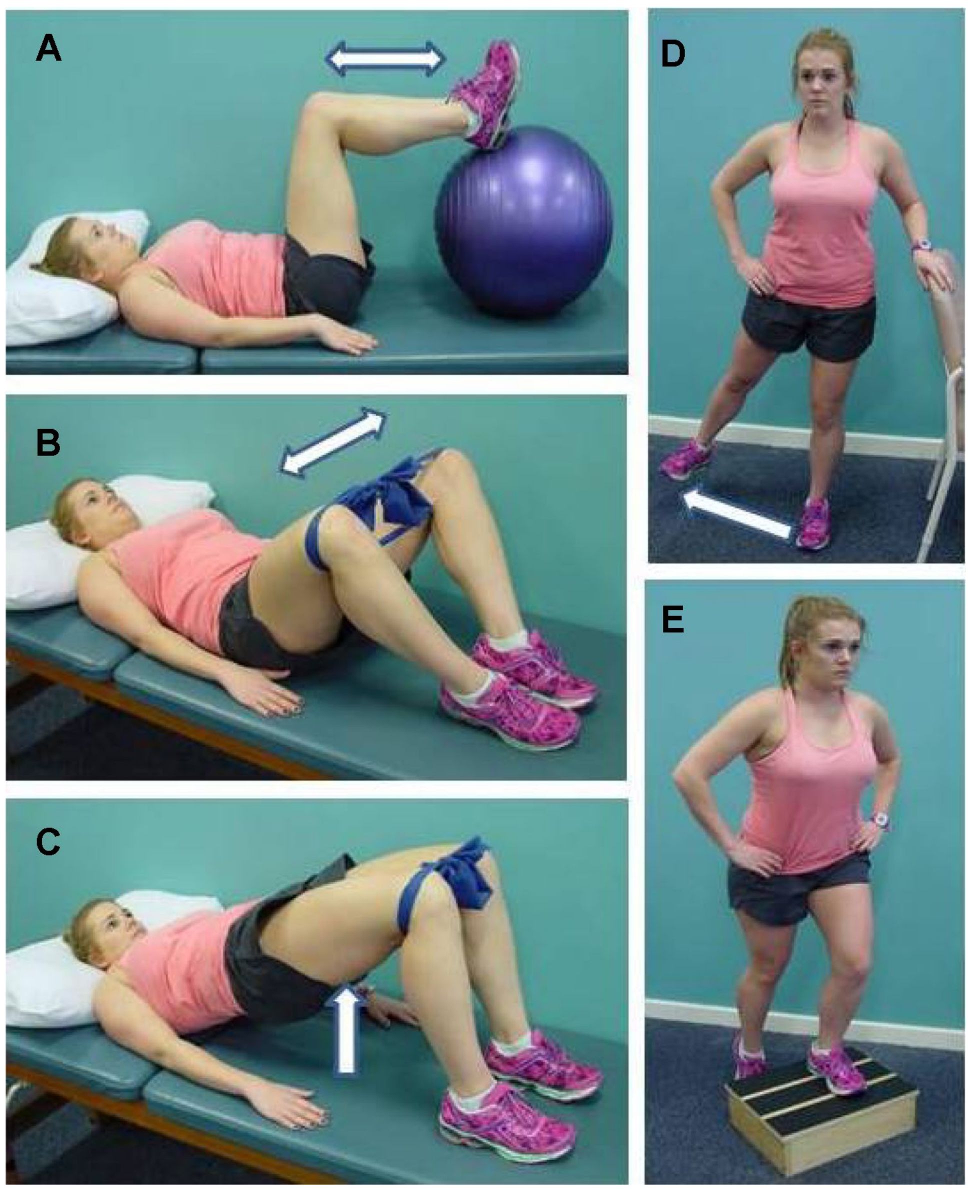

Fig. 2 Phase 4 (4–8 weeks) exercises include range of motion and strengthening exercises for the trunk, thigh and hip/pelvis musculature such as: (A) supine hip flexion with a theraball, keeping within hip flexion motion restrictions, (B) external hip rotation (using theraband) with a focus on control and fluent movement, with a progression in theraband strength and external rotation range of motion as tolerated, (C) bilateral supine bridging (with added isometric abduction load using theraband resistance as tolerated, ensuring the hips, knees and feet remain in alignment and load is distributed evenly between both limbs), (D) standing hip abduction (without added resistance) whereby the swing limb is the operated side, and ensuring there is no ipsilateral trunk lean and/or pelvic rotation throughout, and (E) the initiation of weight bearing functional exercises including step ups, ensuring the drive is through the operated (step) limb and assistance is employed if required to ensure good trunk and lower limb alignment

during normal daily activities with normal, pain-free and unaided gait. While phase 4 and 5 strengthening exercises should be continued, it is thought that muscular activation levels ≥ 40% maximal volitional isometric contraction (MVIC) are required for strength gains [65–67]. Therefore, a combination of high and very high hip abductor muscular activation exercises [61] may be introduced (after sustained full WB with good alignment has been achieved) to achieve this desired loading response (Table 4, Fig. 4), albeit dictated by the surgery, individual patient response to loading, progression and conditioning, functional capacity and goals. Regardless of individual patient goals, pre-disposing biomechanical deficits must first be addressed.

Phase 7: 6–24 months post-surgery

While patients should be relatively pain-free in daily activities by six months, in our experience, the full recovery of muscular strength and function (pending diligent rehabilitation) can take 12–24 months. Within this phase, patients should be able to return to a pain-free and active lifestyle. Patients would be expected to achieve hip abductor strength on the operated limb within 95% of the contralateral limb, tolerate prolonged walking distances and effectively negotiate uneven terrain and soft sand. Therefore, continual exercise prescription that permits ongoing gains in functional strength, as well as addresses any pre-disposing biomechanical deficits, should be undertaken.

Clearly, many patients undergoing HAT repair remain satisfied with the reduction in pain and improvement in the ability to perform activities of daily living and participate in recreational activities [24]. However, for patients who would like to return to higher levels of recreation and/or sporting activities, individual exercise programs targeting specific needs should be prescribed and adhered to. Specific work and/or recreational activities may require ergonomic and/or technique

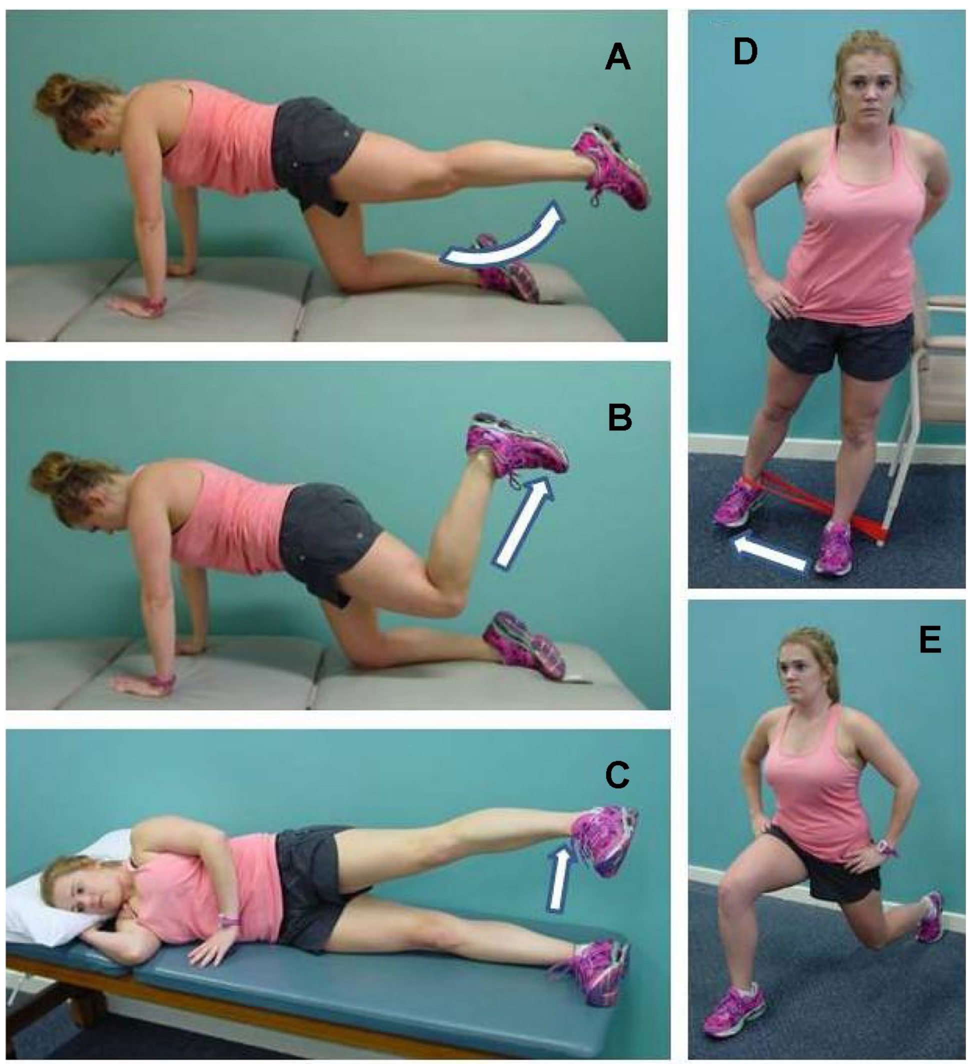

Fig. 3 Phase 5 (8–12 weeks) exercises may include: prone hip extension with an (A) extended and (B) flexed knee, ensuring good core and trunk control and the avoidance of excessive lumbar extension and/or pelvic rotation, (C) side-lying hip abduction ensuring good concentric and eccentric control without pelvic rotation and/or external rotation of the operated limb being abducted, (D) standing hip abduction using theraband, with the moving limb initially the operated side and either free to swing (as shown) or in contact with the ground throughout the movement on a free-sliding device (for enhanced proprioceptive feedback), and ensuring there is no ipsilateral trunk lean and/or pelvic rotation throughout (this can also be undertaken on both sides), and (E) varied weight bearing progressions such as lunges, ensuring an upright trunk and assistance (i.e. a chair or stick) as required, with adequate distance between the front (operated) and back limbs, as well as adequate distance from side-to-side ensuring the avoidance of internal rotation and/or adduction of the operated limb

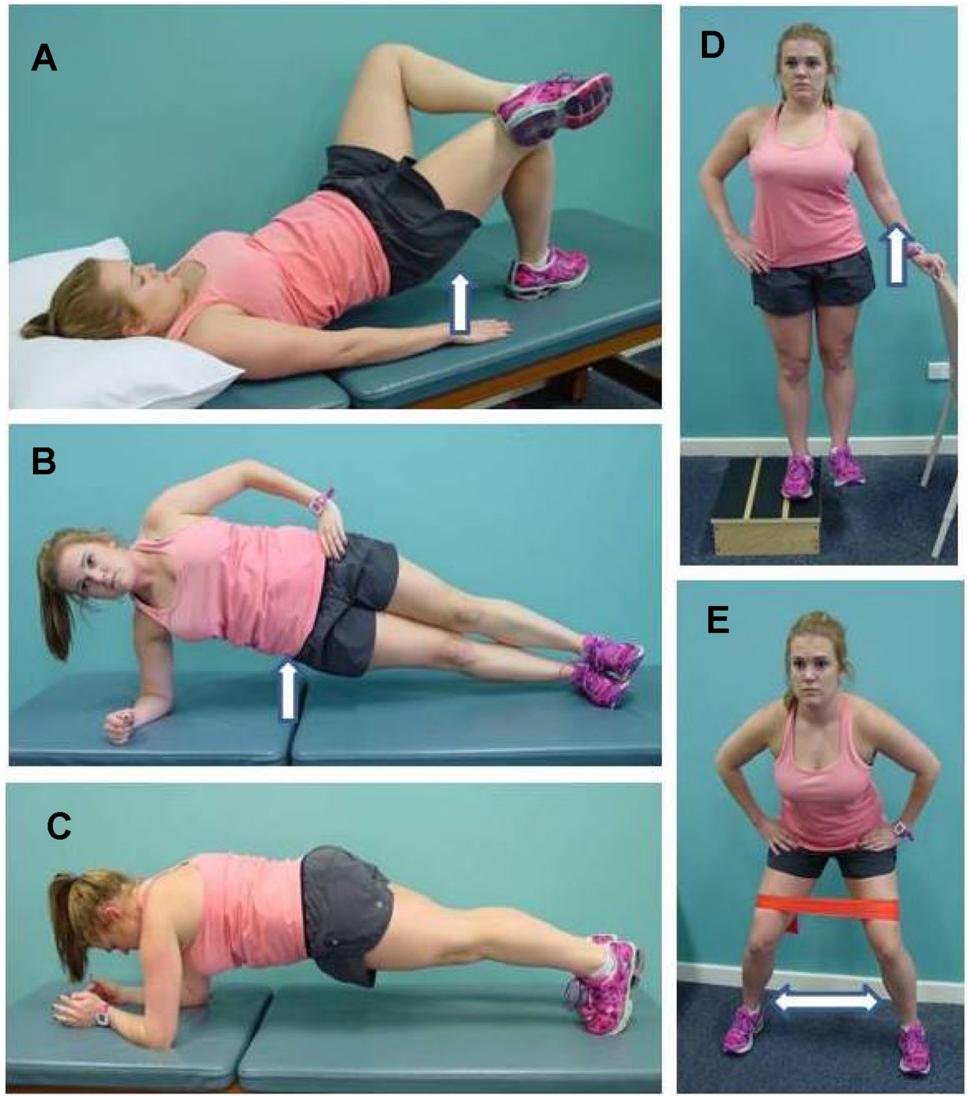

Fig. 4 Phase 6 (3–6 months) exercises may include: (A) single limb supine bridges, ensuring the operated weight bearing limb is not adducted at the hip and can be undertaken with the non-operated (non-weight bearing) limb crossed over (as shown), straight out from the body with the knee flexed or extended, or even gently resting on the heel/toe based on the physical conditioning of the patient, (B) side bridging and (C) prone bridging (plank) ensuring good technique and the avoidance of hip drop in either, (D) pelvic hitching whereby the operated limb is weight bearing and can be undertaken on the ground or a small step (as shown) and with assistance if required, though ensuring that the contralateral non-weight bearing limb does not fall beyond horizontal and into an adducted position, and (E) lateral band side-steps (or 'crab walks') whereby trunk position (upright or flexed) and the positioning of the band can be altered based on patient comfort, convenience and the degree of hip abductor activation that may be desired (i.e. the band can be moved progressively further down the limbs and around the feet for increased hip abductor loading)

modification to avoid provocative positions and/or movements. Rehabilitation for a return to a specific sport requires an understanding of the demands of the sport, though the timing of return will be dependent on several factors including the tissue maturation process, the mental preparedness and general physical function of the patient.

Limitations

The presented study acknowledges some limitations. First, while the proposed rehabilitation guide has sought to synthesize the more recently published literature outlining the rehabilitation of patients after HAT repair, combining it with the extensive clinical experience and publication output of the authors on the topic, it does remain the opinion of the authors and is certainly not an international consensus. However, given the lack of any existing evidence investigating rehabilitation and management practices after HAT repair, with currently no published guides on the topic to better direct the surgeon and/or therapist, we believe this manuscript serves as an important first step. Second, the current study sought to synthesize the rehabilitation detail provided within clinical HAT repair studies published over the prior 3 years, and we acknowledge that studies preceded that time frame and may provide additional information on the topic.

Conclusions

Research focused specifically on rehabilitation after HAT repair does not exist despite the more recent emergence of published literature documenting patient outcomes after a variety of HAT surgical repair methods. Until now, no detailed guidance to clinicians is available in the management of these patients. Post-operative rehabilitation should be individualized based on variables including patient demographics and surgery characteristics, the physical function and compliance of the patient, and an individual's tolerance to pain following surgery and during prescribed exercises. While variation will occur based on the individual as well as the array of surgical techniques that exist, the progression in WB, ROM and specific hip abductor loading presented in the current rehabilitation synopsis aligns with other studies reporting patient outcomes after an array of surgical techniques. With this, we present a graduated rehabilitation protocol with the current published rehabilitation content in mind, together with successful outcomes in patients undergoing HAT repair through our own institutions [13, 24]. However, we acknowledge that research is needed to better evaluate the benefit of varied rehabilitation regimens after HAT repair.

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Declarations

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