Journal of Hip Preservation Surgery Vol. 0, No. 0, pp. 1–10
doi: 10.1093/jhps/hnaa030
Research article

Pre-operative comparisons for a return to running protocol in recreational athletes following hip arthroscopy

Alan W. Reynolds[1], Ryan P. McGovern[2]*, Beth Nickel[1], and John J. Christoforetti[2]

[1]Department of Orthopaedic Surgery, Allegheny Health Network, Pittsburgh, PA 15224, USA and
[2]Department of Orthopaedic Surgery, Texas Health Sports Medicine, Allegheny Health Network, 5858 Main Street, Suite 210, Frisco, Texas 75034, USA.
*Correspondence to: R. P. McGovern. E-mail: RyanMcGovern@texashealth.org
Submitted 25 February 2020; Revised 8 May 2020; revised version accepted 12 June 2020

ABSTRACT

The purpose of the current study was to present pre-operative comparisons for recreational athletes attempting a return to running following hip arthroscopy, and the return to running progression protocol used to guide them. A prospective, non-randomized cohort study was conducted to evaluate recreational athletes that returned to running following hip arthroscopy. Return to running was the primary outcome measure and defined as the ability to run at least one mile three times weekly while maintaining patient-reported relief of pre-operative symptoms. Patients included were correlated with the following pre-operative patient-reported outcome measures: hip outcome score (HOS), 12-item international outcome tool (iHOT-12), visual analog scale for pain (VAS) and the Short-Form Health Survey (SF-12). Of the 99 included patients, 94 (95%) returned to running successfully with an average return of 4.8 months. There was no statistical difference in pre-operative comparisons between patients that returned to running and did not return to running ($P \geq 0.154$). Evaluation of pre-operative clinical outcomes demonstrated no statistical difference between individuals that returned and did not return to running ($P \geq 0.177$), but a large difference between the two groups was identified for HOS-ADL (64.8 versus 53.7, returned versus did not return), iHOT-12 (33.8 versus 25.4) and VAS (58.6 versus 69.3). Patients who returned to running demonstrated similar intraoperative procedures as those that did not return to running ($P \geq 0.214$). The current study successfully establishes a management plan and progression protocol for patients identifying a return to recreational running following hip arthroscopy. Level of evidence: 3.

INTRODUCTION

The use of hip arthroscopy in the treatment of both intra- and extra-articular hip pathology has increased in recent years as surgical techniques and diagnostic accuracy continue to be refined, with a 460% increase reported from 2005 to 2013 [1]. Many patients undergoing these procedures are young, active individuals with an expectation of returning to pre-injury activity levels. While rate of return to sport in the elite or professional level athlete has been established [2–5], there is a limitation in research regarding return to activity for the recreational or amateur athlete.

A successful return to running is frequently identified as a pre-operative goal for recreational athletes undergoing hip arthroscopy. Although the return to running may not be a reasonable outcome for every patient, studies have demonstrated a successful return with low risk of complications [6–8]. Specifically, 94% at 2 years [8] and 78% of patients at 5 years [6] have reported a successful return to running following hip arthroscopy for intra-articular pathology. While these studies have demonstrated a high incidence of return, substantial heterogeneity exists amongst the specific rehabilitation protocols in the current peer-reviewed literature [7, 9, 10].

Rehabilitation interventions are typically used to guide the patients progression back to activity and is integral to successful outcomes following hip arthroscopy [7]. Several different rehabilitation protocols have been described in the literature, both to achieve a successful return to day-to-day function and athletic performance [7, 11–14]. While rehabilitation protocols should be focused on returning patients to specific activities, there is currently a limitation in outcome-based evidence to support the published protocols [7, 9]

Despite the increased expectation of patients returning to activity following hip arthroscopy, there is a limitation in evidence-based rehabilitation protocols. Specifically, there is a limitation in established return to running progression protocols and their demonstrated effects on clinical outcomes [9]. The purpose of the current study was to present pre-operative comparisons for recreational athletes attempting a return to running following hip arthroscopy, and the return to running progression protocol used to guide them.

MATERIALS AND METHODS

Patients

A registry database of prospectively collected hip arthroscopy cases was queried from July 2015 to October 2018. Data were prospectively collected on 390 patients undergoing primary hip arthroscopy by the senior author (J.J.C.). All subjects and parents/guardians (when applicable) approved and signed the written informed consent and authorization to disclose protected health information for a research study established under the ****—institutional review board.

Inclusion criteria for this study included: patients who were able to consent for participation, parental/guardian permission (informed consent) and if appropriate, child assent, the ability to read and understand English and consent for themselves, age 13–60 years, diagnosed intra-articular pathology with primary hip arthroscopy recommended by the treating orthopedic surgeon, patients who reported recreational running as a pre-operative activity with a desire to return post-operatively, a return to running identified pre-operatively by treating orthopedic surgeon as a realistic outcome, completed office medical records and operative note, and follow-up of at least 6-month following surgery. Exclusion criteria for this study included: any patient failing to sign the informed consent, previous ipsilateral hip surgery, ≥Tönnis 2 osteoarthritis and no follow-up after at least 6-month following hip arthroscopy.

Return to recreational running was the primary outcome measure and defined as the successful ability to run at least one mile three times weekly, while maintaining patient-reported relief of pre-operative hip symptoms. Other data collected included demographic information, diagnoses, procedures performed, and patient-reported outcome measures (PROs).

Clinical evaluation

Patient demographics previously correlated with impact on outcomes following pre-arthritic hip arthroscopy were meticulously recorded along with key physical examination findings, radiographic parameters and magnetic resonance imaging (MRI) results [15–17]. Patients were imaged with a weight-bearing superior anteroposterior (AP) view of the pelvis, lateral view of the proximal femur (Dunn 45° view) and a standing false profile view of the pelvis [17, 18]. Pre-operative radiographic measurements were made by a trained member of the research team blinded to the surgical method chosen. Simple structural instability measurements (anterior and lateral center edge angles, Tönnis angle) and femoral sphericity measures (alpha angles) were recorded for all patients. Tönnis classification for osteoarthritis was assessed on the AP view and gives an objective evaluation for the severity of degeneration [19]. MRI techniques included imaging in the oblique plane along the femoral neck as well as standard coronal, sagittal and axial plane views of the hip and pelvis to evaluate for soft-tissue conditions of the hip joint and surrounding musculoskeletal structures [16].

Pre-operative care

Prior to surgical consideration, all patients performed a 6–8-week rehabilitation intervention focused on patient education, activity modification, limitation of aggravating factors, an individualized physical therapy program and a home-exercise program. Supervised physical therapy was provided by the rehabilitation specialist of the patients choosing 1-day a week. The specific protocol for the physical therapist/rehabilitation expert is provided in Fig. 1. The home-exercise program distributed to the patients was from previously established study [20, 21]. Participants completed four exercises of the home-exercise program on the week-days when they were not participating in the individualized physical therapy intervention. The patients were instructed to cycle through the 12-total exercises during the week, while not repeating an individual exercise on back-to-back days. Patients who failed to improve with conservative management and were deemed surgically viable by the treating orthopedic surgeon proceeded to hip arthroscopy.

Phase I: Analysis of sport position needs for the individual patient
- Identify if a flexed, adducted, internally rotated position is required or achieved upon common sport motions
  - Video feedback using smartphone or digital video to assess
    - Single leg landing
    - Direction change stance phase position
    - Key sport / work activity squat or pivot positions
- Assess and instruct if position modification can assist in avoidance of deep hip flexion/adduction/internal rotation

Phase II: Analysis and treatment of core weakness
- Test for core deficiency
- Instruct and cue foot-on-ground supine core engagement exercise

Phase III: Analysis and treatment of hip muscular/capsular balance
- Closed chain gluteus maximus strength training
- Manual posterior hip capsular mobilization if tolerated by patient
- Anterior 1/3 gluteus medius manual roll or massage
- Prone hip flexor stretches for rectus /psoas

Phase IV: Sport specific drills
- Assess sport specific needs/techniques
  - Kicking (soccer), throwing/ batting (baseball), skating (hockey)

Fig. 1. Pre-operative physical therapy protocol.

Intraoperative technique

Patients were placed in a supine position on a hip arthroscopy minimal-post table after properly protecting the pressure areas. Traction was applied to the operative hip using a limb spar and fluoroscopic visualization. The hip was accessed via an anterolateral portal with a 70° lens arthroscope. Subsequently, the mid-anterior portal was created, and an arthroscopic blade was used to perform the capsulotomy. Intraoperative details were recorded by the treating surgeon including operative procedures and standardized description of diagnostic arthroscopic findings. Following each procedure, the hip was reduced into the acetabulum and the arthroscope was then withdrawn. The fluoroscope views confirmed concentric reduction. The skin was then closed sterilely, and a sterile dressing applied. The skin of the perineal area was inspected and free of traction related injury. A hip orthosis (T-Scope Hip; Breg, Inc.) was applied.

Post-operative care

Patients were seen in office by the treating orthopedic surgeon the day after surgery, followed by initiation of physical therapy that same day. All hip arthroscopy patients were prone in bed for the first post-operative night with abduction cylinder and boots. Patients were limited to 20 lbs. foot-flat weight bearing with crutches for the first 2-week following surgery. Weight-bearing restriction was used to place the lowest possible force across the hip joint to allow for recovery of capsuloligamentous stability and protect healing bone in setting of osteoplasty. Upright, plantigrade gait was taught to avoid hip flexor irritation. They were pre-fit for a hip orthosis (T-Scope Hip; Breg, Inc.) by a trained medical equipment professional, began wearing the brace immediately following surgery and were checked for fit during the initial post-operative visit. The brace was set to allow full hip extension and 90° of hip flexion. The patients were always instructed to wear the brace outside of continuous passive motion or in formal physical therapy sessions. Extended use of the crutches and hip brace for an additional 4 weeks was initiated at the treating orthopedic surgeon's discretion for patients undergoing microfracture and/or labral reconstruction.

Passive motion was initiated immediately after surgery for prevention of adhesion formation within the joint. A continuous passive motion machine (CPM) was used for the first 2 weeks for 6 h-a-day (3–2-h sessions) following hip arthroscopy. A CPM was used to allow for formation of functional capsular volume after capsulotomy, intraoperative traction and to reduce development of adhesions between capsulotomy or repair surfaces and osteoplasty sites. Passive hip pendulums for 1 h-a-day (3–20 min sessions) were performed based on a previously performed study [22]. Along with passive motion, patients were instructed to lay prone 1 h-a-day (3–20 min sessions).

Physical therapy

Formalized physical therapy was for one visit-a-week for the first 6 weeks and increasing to two visits-a-week following an in-office visit with the treating orthopedic surgeon 6-week post-operative. Supervised physical therapy was performed up to 4-month postoperative if deemed necessary to achieve specific patients' goals of a return to athletic activity. Physical therapy focused on the patient's native gait pattern, the needs of their functional positioning during work, life and sport, and any observable or modifiable conflicts. Specifically, gait normalization was focused on the timing and position of normal stance/swing phase gait for each patient. Core strengthening, lumbopelvic control and functional ROM and performance were key tenants in the progression of the rehabilitation protocol which is presented in Fig. 2.

Return to running progression protocol

A standard return to running progression protocol was implemented following the patients 3-month post-operative visit with the treating orthopedic surgeon. Prior to release for the return to running progression, clinically each patient had to demonstrate a normalized gait pattern and functional movement performance. Unilateral functional performance was compared bilaterally with the single leg squat test (SLST) by the treating orthopedic surgeon. The standardized protocol for administering and evaluating the SLST was based on a previously validated study for assessing patients with pre-arthritic hip pain [23].

Following clearance by the treating orthopedic surgeon, a standardized 4-week 'month-to-mile' program was begun by all patients. This included 3 days per week of running, 3 days of optional, non-impact cardio and 1 day of total rest. Each running day included completing 1 mile on a track with a combination of running and walking, with a progressively increasing proportion of running. Further details of the program can be found in Fig. 3. Prior to release several key points of the running progression protocol were explained to each patient and are presented in Fig. 4. In addition to this running protocol, all patients were also participating in Phase IV individualized therapy interventions, two times per week focusing on functional strength training for a return to running and activities of daily living.

Patient-reported outcomes

Specific PROs included the Hip Outcome Score—Activities of Daily Living (HOS-ADL) [24], Hip Outcome Score—Sports Specific Subscale (HOS-Sport) [24], the 12-item International Hip Outcome Tool (iHOT) [25] and the Short-Form Health Survey (SF-12) were collected pre-operatively. Visual analog scale (VAS) [26] for hip pain (0, no pain; 100, worst imaginable pain) was collected for each patient at a minimum 6-month follow-up from surgical intervention.

Statistical analysis

Pre-operative comparisons between the two groups were analyzed using *t*-tests or Fisher's exact test, depending on the category of data. Fisher's exact test was used to compare intraoperative pathological findings and surgical procedures that were performed. An independent *t* test was performed for each continuous, pre-operative PROs (HOS-ADL, HOS-Sport, iHOT, SF-12 and IHOT). These analyses determined whether the mean pre-operative PROs were significantly different between individuals that returned to running and those that did not following hip arthroscopy. All statistical analysis was performed with an a-priori alpha set of $P < 0.05$. All data were analyzed using a common statistical software program (IBM SPSS Statistics, Version 25, Armonk, NY).

RESULTS

This retrospective analysis of prospectively collected information included a total of 390 patients who underwent hip arthroscopy. A total of 124 patients expressed a pre-operative goal of returning to recreational running. From this population, 99 (80%) patients (60 female and 39 male) with an average age of 30.0 ± 11.1 years, height of 171.6 ± 9.6 cm, weight of 71.7 ± 15.5 kg and body mass index 24.2 ± 4.0, met the inclusion criteria and were included in this study. Of the 99 included patients, 94 (95%) returned to running successfully with an average return of 4.8 months. Of the five patients that did not return to running, two (40%) reported their decision was not due to their hip condition and preferred to utilize other methods of cardiovascular endurance. The other three (60%) patients discontinued based on the long-term effects of impact on the hip joint and the possibility of accelerating the progression of osteoarthritis with further participation in recreational running. Pre-operative comparisons between the two groups are presented in Table I. There was no statistical difference between individuals that returned to running and did not return to running ($P \geq 0.154$). Ninety (96%) patients that returned to running successfully reported an atraumatic onset of symptoms, while all patients that did not return to running presented with an atraumatic onset. A comparison of pre-operative clinical outcomes for the 94 patients who successfully returned to running and the 5 who did not are presented in Table II. Although there was no statistical difference between individuals that returned and did not return to running

Phase I: First Day Postoperative to 2 weeks Postoperative
Goal: Navigate early recovery period safely, avoiding infection, instability or disruption of repair, and flexion contracture
1 visit/ week

- Warm up Sessions: 20 minutes on stationary bike.
- GameReady: Ice session to hip area.
- Therapist performs hip pendulums and cues to supervise core training.
- Reinforce upright posture and foot flat gait.
- Supine, foot flat on table core engagement exercises to begin activating core pelvic control without engaging hip flexors or pelvic tilt.
- Manual lymphedema message if noticeable swelling.

Please help reinforce the following:

- Stationary bicycle: Instruct use of upright stationary bike with seat height limiting hip flexion to 90° and knee range 30° to 120°. Operative leg to" take a ride" and avoid active flexion. 20 minutes daily sessions at home or gym recommended.
- Crutch use for patients under age 50, walker for all gluteus medius repair or age over 50. (This may vary based on situation)
- 20 lb. foot flat gait. Focus upright posture and full stride
- CPM - 2-hour sessions, 3 times daily (total 6 Hours).
- Prone Hanging – 20 minutes after each CPM session.
- Hip Pendulums – 20 minutes after each CPM session.
- Instruct hip pendulum exercises for performance by home care giver. 30° and 70° small circles of thigh with patient relaxed.
- Foot Pumps.
- Breg Hip Orthosis: wear when out of CPM; wear at night Setting 0-90°.

Phase II: Week 2-6 (Patient to see MD prior to initiation)
Goal: wean from crutches and achieve normal gait and seating positions with ADL's
1 visit/ week

- Therapist to instruct single crutch gait with full weight bearing on operative leg placing crutch in arm opposite operative side. Single crutch gait for 3-5 days then weans to crutch free ambulation.
- Therapist to advise and instruct timing and position of normal stance / swing phase gait.
- Therapist to reinforce core/abdominal exercises and anterior hip capsular stretch.
- Prone lying figure of four capsular stretch initiated.
- If center owns an Alter-G treadmill, patient may use for 50% weight bearing exercise.
- If center owns aquatic, patient may engage in aqua walking at week 3, but NO repetitive hip flexion underwater exercise or flutter kick/ breaststroke kick.

Phase III: Week 6 to 12 (Patient to see MD prior to initiation)
Goal: Learn Functional Avoidance Patterns, posterior capsular stretch to achieve IR at 90° flexion of 25°
Increase to 2 visits/ week

- Patients will be given a home-exercise program in office that they will participate in on non-formal PT days (we encourage our patients to bring in this program so that therapists can familiarize).
- Therapist to evaluate dynamic functional maneuvers (single leg hop, step downs, direction changes in stance phase, single leg squat) and instruct functional avoidance of flexion adduction, internal rotation position.
- Quads/ Hamstrings strength and flexibility within comfort range of hip focusing on closed chain exercise.
- Prone Gluteus Maximus open chain exercise OK at this phase.
- Continue core training focus.

Phase IV: Week 12-20 (Patient to see MD prior to initiation)
Goal: Return to Sport
Visits vary by needs

- Patient can begin month-to-mile running progression under MD's direction.
- Patient will continue home-exercise program that was provided by MD's office.
- Therapist to work with patient and coaching staff on sport-specific skill and strength moves to facilitate cardio and strength appropriate for sport return.

Fig. 2. Post-operative physical therapy protocol.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1	Walk Run Walk Walk	Off/ Non-Impact	Walk Run Walk Walk	Off/ Non-Impact	Walk Run Walk Walk	Off/ Non-Impact	Total Rest
Week 2	Walk Run Run Walk	Off/ Non-Impact	Walk Run Run Walk	Off/ Non-Impact	Walk Run Run Walk	Off/ Non-Impact	Total Rest
Week 3	Walk Run Run Run	Off/ Non-Impact	Walk Run Run Run	Off/ Non-Impact	Walk Run Run Run	Off/ Non-Impact	Total Rest
Week 4	Run Run Run Run	Off/ Non-Impact	Run Run Run Run	Off/ Non-Impact	Run Run Run Run	Off/ Non-Impact	Total Rest

Fig. 3. 'Month-to-Mile' return to running progression protocol.

1. Performed on flat ground – middle school, high school or college track (1/4-mile lap length).
2. Warm-up with 15 minutes of core exercises and light stretch.
3. This progression is **NOT** a cardio workout.
4. Days "off" between running may be filled with non-impact cardio (bicycle, elliptical, swimming) but "total rest" days are for "**TOTAL REST.**"
5. Each entry represents 1 lap (or ¼ mile).
6. Advance to next "Week" only if pain free on Monday.
7. Once completed, may increase mileage weekly, no greater than 2 miles and no greater than one mile per session.
8. Speed and intensity should increase throughout the week's effort.

Fig. 4. Key points for 'Month-to-Mile' return to running progression protocol.

($P \geq 0.177$), a large difference between the two groups was identified for HOS-ADL (64.8 versus 53.7, returned versus did not return), iHOT-12 (33.8 versus 25.4) and VAS (58.6 versus 69.3).

Intraoperative findings for both the return and did not return to running groups is presented in Table III, respectively. Patients who returned to running demonstrated similar intraoperative procedures as those that did not return to running ($P \geq 0.155$). Acetabular labrum tears were the most common diagnosis and were present in similar percentages of patients who returned and did not return with 91% and 100% respectively. Eighty-one percent of patients who returned to running had a bony abnormality prior to surgical intervention. Femoroacetabular impingement was present in 62% and 100% of the respective groups, with cam impingement accounting for similarly large numbers for patients that returned and did not return to running with 79% (cam and mixed pattern) and 100%, respectively. Borderline dysplasia ($\geq 18° – \leq 25°$ on anterior and/or lateral center edge angles) [27] and dysplasia ($< 18°$ anterior and/or lateral center edge angles) represented 19% and 20% of patients that returned or did not return to running, respectively.

Similarly, there were no statistically significant differences in operative procedures for patients who returned to running and those that did not ($P \geq 0.112$) and is presented in Table IV. The most common procedure performed in 80% of both groups was acetabular labral repair. Femoroplasty was also primary performed with an incidence of 40% in both groups, while acetabuloplasty was performed in 24% and 60% of patients who returned to running and those that did not, respectively. All ligamentum teres partial tears present were treated with debridement.

Table I. Pre-operative comparison for patients who returned and did not return to running following hip arthroscopy

	Returned (N = *94*)		*Did not return* (N = *5*)		
	Mean	*SD*	*Mean*	*SD*	*Significance* P-*value*
Age (years)	29.9	11.2	28.2	11.4	0.743
Height (cm)	171.7	9.7	169.5	6.0	0.664
Weight (kg)	72.1	15.5	63.5	14.7	0.280
Body mass index (kg/m^2)	24.3	4.0	21.9	3.4	0.246
ACEA	31.3°	6.7°	26.5°	2.1°	0.154
LCEA	30.6°	5.9°	28.3°	3.6°	0.377
AP alpha	49.1°	14.4°	50.3°	18.1°	0.857
Dunn alpha	53.5°	10.7°	60.0°	8.5°	0.187
Tönnis angle	3.8°	4.7°	6.7°	2.6°	0.169
Gender					
Male	38 (40%)		1 (20%)		0.646
Female	56 (60%)		4 (80%)		
Tönnis grade					1
0	65 (69%)		4 (80%)		
1	29 (31%)		1 (20%)		

SD, standard deviation; ACEA, anterior center edge angle on faux profile radiographic view; LCEA, lateral edge angle on anteroposterior radiographic view; AP alpha, alpha angle on anteroposterior radiographic view; Dunn Alpha, alpha angle on lateral Dunn 45° radiographic view.

Table II. Pre-operative patient-reported outcomes comparison for patients who returned and did not return to running

	Returned (N = *94*)		*Did not return* (N = *5*)		
	Mean	*SD*	*Mean*	*SD*	*Significance* P-*value*
HOS-ADL (out of 100)	64.8	16.1	53.7	15.2	0.177
HOS-Sport (out of 100)	43.9	20.0	44.4	25.7	0.960
iHOT-12 (out of 100)	33.8	15.6	25.4	15.7	0.244
SF-12 mental	50.8	10.2	47.9	10.8	0.534
SF-12 physical	36.4	7.5	34.6	13.2	0.621
VAS (out of 100)	58.6	21.0	69.3	10.9	0.262

HOS-ADL, hip outcome score activities of daily living; HOS-Sport, hip outcome score sports specific subscale; iHOT-12, 12-item international hip outcome tool; SF-12 mental, the short-form health survey for mental health; SF-12 physical, the short-form health survey for physical health; VAS, visual analog scale for pain.

Table III. Intraoperative findings for patients who returned and did not return to running following hip arthroscopy

	Returned (N = 94)	*Did not return* (N = 5)	*Significance* P-*value*
Acetabular labral tear	86 (91%)	5 (100%)	1
Femoroacetabular impingement	58 (62%)	5 (100%)	0.155
Cam deformity	34 (58%)	4 (80%)	0.640
Pincer deformity	12 (21%)	1 (20%)	1
Mixed pattern	12 (21%)	—	0.573
Structural instability	19 (20%)	1 (20%)	1
Borderline dysplasia	15 (79%)	1 (100%)	1
Dysplasia	3 (16%)	—	1
Femoral retrotorsion	1 (5%)	—	1
Ligamentum teres pathology	30 (32%)	1 (20%)	1
Partial tear	30 (100%)	1 (100%)	1

Table IV. Pre-operative procedures performed for patients who returned and did not return to running following hip arthroscopy

	Returned (N = 94)	*Did not return* (N = 5)	*Significance* P-*value*
Acetabular chondroplasty	23 (24%)	3 (60%)	0.112
Acetabular labral treatment	86 (91%)	5 (100%)	1
Debridement	17 (20%)	1 (20%)	1
Repair	69 (80%)	4 (80%)	1
Acetabuloplasty	26 (28%)	2 (40%)	1
Femoroplasty	37 (40%)	2 (40%)	1
Ligamentum teres treatment	30 (32%)	1 (20%)	1
Debridement	30 (100%)	1 (100%)	1

DISCUSSION

The main finding of the current study was that the standardized return to running progression protocol for patients undergoing hip arthroscopy was successful in returning 95% of recreational athletes to running at an average of 4.8 months post-operatively. The current study successfully establishes a conservative management plan and progression protocol for patients identifying a return to recreational running following hip arthroscopy. While there was no statistically significant difference between the two groups, the patients who did not return to running did not provide a large enough number to elicit a high statistical power for comparison between the two groups.

In terms of predicting which patients may or may not return successfully, there were no significant differences in pre-operative comparisons between the two groups. Those who did return to running reported greater ability to perform activities of daily living, although not significantly

different. Interestingly, sports-related activity and hip-specific PROs demonstrated no difference between these two groups. A patient's perception of their pre-operative athletic function did not correlate with a likelihood of returning to running. It is possible that lower pre-operative activities of daily living scores are reflective of an intrinsic patient characteristic or possibly more severe and debilitating pathology. Furthermore, it should be noted that 31 (31%) of all patients included in this study had ligamentum teres pathology with 30 (97%) having partial tears treated with debridement and 1 (3%) patient having a reconstruction for a complete rupture. This relatively high incidence of ligamentum teres pathologies reported correlates with previous studies that establish a high incidence of these pathologies in patients returning to running after hip arthroscopy [6, 8]. The current study presents interesting areas for further investigation. As has been previously reported, a stronger base of evidence is needed for post-operative care. This study establishes a benchmark for return to running based on a progression protocol to which future studies and other programs can be compared.

In comparing the current study to those performed previously, this study demonstrated a high rate of 95% for return to running following hip arthroscopy. Levy *et al.* [8] demonstrated similar results of 94% (48/51) of patients returned to running at a mean 8 ± 4.2 months. While this study included both recreational and competitive runners, the group defined as recreational was comprised of 26 patients. Recently, Chen *et al.* [6] performed a retrospective review of 60 runners who underwent hip arthroscopy and had a minimum of 5-year follow-up. This cohort demonstrated a return rate of 78% (39 patients, 41/52 hips), of which 79% (31/39) of recreational runners successfully returned to running following hip arthroscopy [6]. The current study demonstrates a high rate of return for a broad group of patients considering surgical intervention, with the specific intention of returning to running post-operatively regardless of ability.

The interval return to running concept has been previously reported as a standard method to return athletes to sport. The unique aspects of the current progression protocol include the comprehensive consideration of mental and physical restoration in the context of available basic science of bone. Endurance athletes and other highly active individuals who self-identify as 'runners' demonstrate characteristic exercise dependency for various mental and physical reasons. The absence of daily activity is a cause of stress and anxiety and can lead to overuse. When returning from surgery which occurs after prolonged pre-operative absence from sport, depression is also common [28]. This protocol carefully includes accountability for 7 days a week of guided activity. It communicates a definitive plan and concurrently allows for confidence in the patient that their running will improve. The intentional inclusion of a seventh day of complete rest helps to educate and include needed complete recovery time into their life to improve chances of durability. The distances selected are arbitrary, and the direction to run on a quarter mile track control surface and distance factors. The principle of biology of bone turnover followed is that the breakdown cycle occurs at a faster rate than new bone deposition and stress reorientation [29, 30]. This ratio is respected by limiting loading days and loading rates (jog versus walk) over a 4-week period, following the accepted timeline of maturation of soft callus in a fracture setting [29]. The inclusion of non-impact cardio on alternate days allows the boney insertions and myotendinous units to develop and mature stress reorientation to prepare for continued addition of strain. This structure also facilitates daily exposure to exercise-related endorphin release which boosts morale. Careful instructions on the protocol advise the patient to wait to progress to the next step until completely pain free.

There are limitations to this study that need to be considered when interpreting the results, including that there was no control group for comparison of the protocol. Success of returning to running was based on self-reporting by patients and was not independently verified by the authors, except in some cases where patients had documented running in physical therapy notes. An objective measure of runn\ing performance pre- and post-operatively was not provided. Finally, the patients who did not return to running did not provide a large enough number to elicit a high statistical power for comparison between successful and unsuccessful runners. Future studies should provide greater detail in evidence for the specific rehabilitation protocol administered along with the running progression. It may be possible to compare cohorts with control groups or even randomized assignments and prospective studies. Further protocols tailored to patient demands and stratified by expectations would also be possible. Longer-term follow-up would also contribute to this and further help define predictors for patients to achieve their goals and expectations post-operatively with appropriate pre-operative guidance supported by data.

FUNDING

This work was supported by Allegheny Singer Research Institute, Allegheny Health Network.

CONFLICT OF INTEREST STATEMENT

The authors report the following potential conflicts of interest or sources of funding: J.J.C. is a board member of

the International Society for Hip Arthroscopy, is a paid consultant for Arthrex, and has patents with and receives royalties from Arthrex and Breg.

REFERENCES

1. Maradit Kremers H, Schilz SR, Van Houten HK *et al.* Trends in utilization and outcomes of hip arthroscopy in the United States between 2005 and 2013. *J Arthroplasty* 2017; **32**: 750–5.
2. Jack RA, Sochacki KR, Hirase T *et al.* Performance and return to sport after hip arthroscopic surgery in major league baseball players. *Orthop J Sports Med* 2019; **7**:232596711982583.
3. Rosinsky PJ, Kyin C, Lall AC *et al.* Rate of return to sport and functional outcomes after bilateral hip arthroscopy in high-level athletes. *Am J Sports Med* 2019; **47**: 3444–54.
4. Jack RA, Sochacki KR, Hirase T *et al.* Performance and return to sport after hip arthroscopy for femoroacetabular impingement in professional athletes differs between sports. *Arthroscopy* 2019; **35**: 1422–8.
5. Sochacki KR, Jack RA, Hirase T *et al.* Performance and return to sport after femoroacetabular impingement surgery in national football league players. *Orthopedics* 2019; **42**: e423–9.
6. Chen AW, Craig MJ, Yuen LC *et al.* Five-year outcomes and return to sport of runners undergoing hip arthroscopy for labral tears with or without femoroacetabular impingement. *Am J Sports Med* 2019; **47**: 1459–66.
7. Grzybowski JS, Malloy P, Stegemann C *et al.* Rehabilitation following hip arthroscopy—a systematic review. *Front Surg* 2015; **2**: 21.
8. Levy DM, Kuhns BD, Frank RM *et al.* High rate of return to running for athletes after hip arthroscopy for the treatment of femoroacetabular impingement and capsular plication. *Am J Sports Med* 2017; **45**: 127–34.
9. Kraeutler MJ, Anderson J, Chahla J *et al.* Return to running after arthroscopic hip surgery: literature review and proposal of a physical therapy protocol. *J Hip Preserv Surg* 2017; **4**: 121–30.
10. Rath E, Sharfman ZT, Paret M *et al.* Hip arthroscopy protocol: expert opinions on post-operative weight bearing and return to sports guidelines. *J Hip Preserv Surg* 2017; **4**: 60–6.
11. Bennell KL, O'Donnell JM, Takla A *et al.* Efficacy of a physiotherapy rehabilitation program for individuals undergoing arthroscopic management of femoroacetabular impingement—the FAIR trial: a randomised controlled trial protocol. *BMC Musculoskelet Disord* 2014; **15**: 58.
12. Domb BG, Sgroi TA, VanDevender JC. Physical therapy protocol after hip arthroscopy: clinical guidelines supported by 2-year outcomes. *Sports Health* 2016; **8**: 347–54.
13. Heerey J, Risberg MA, Magnus J *et al.* Impairment-based rehabilitation following hip arthroscopy: postoperative protocol for the HIP ARThroscopy International Randomized Controlled Trial. *J Orthop Sports Phys Ther* 2018; **48**: 336–42.
14. Kuhns BD, Weber AE, Batko B *et al.* A four-phase physical therapy regimen for returning athletes to sport following hip arthroscopy for femoroacetabular impingement with routine capsular closure. *Int J Sports Phys Ther* 2017; **12**: 683–96.
15. Frangiamore S, Mannava S, Geeslin AG *et al.* Comprehensive clinical evaluation of femoroacetabular impingement: part 1: physical examination. *Arthrosc Tech* 2017; **6**: e1993–2001.
16. Geeslin AG, Geeslin MG, Chahla J *et al.* Comprehensive clinical evaluation of femoroacetabular impingement: part 3: magnetic resonance imaging. *Arthrosc Tech* 2017; **6**: e2011–8.
17. Mannava S, Geeslin AG, Frangiamore SJ *et al.* Comprehensive clinical evaluation of femoroacetabular impingement: part 2, plain radiography. *Arthrosc Tech* 2017; **6**: e2003–9.
18. Clohisy JC, Carlisle JC, Beaule PE *et al.* A systematic approach to the plain radiographic evaluation of the young adult hip. *J Bone Joint Surg Am Vol Suppl* 2008; **90**: 47–66.
19. Telger TC, Tönnis D, Legal H *et al. Congenital Dysplasia and Dislocation of the Hip in Children and Adults*. Springer-Verlag Berlin Heidelberg; 1987.
20. McGovern RP, Martin RL, Kivlan BR *et al.* Non-operative management of individuals with non-arthritic hip pain: a literature review. *Int J Sports Phys Ther* 2019; **14**: 135–47.
21. McGovern RP, Martin RL, Phelps AL *et al.* Conservative management acutely improves functional movement and clinical outcomes in patients with pre-arthritic hip pain. *J Hip Preserv Surg* 2020; **7**: 95–102.
22. Sauber R, Saborio G, Nickel BM *et al.* Pendulum exercises after hip arthroscopy: a video technique. *Arthrosc Tech* 2016; **5**: e897–900.
23. McGovern RP, Christoforetti JJ, Martin RL *et al.* Evidence for reliability and validity of functional performance testing in the evaluation of nonarthritic hip pain. *J Athl Train* 2019; **54**: 276–82.
24. Martin RL, Kelly BT, Philippon MJ. Evidence of validity for the hip outcome score. *Arthroscopy* 2006; **22**: 1304–11.
25. Griffin DR, Parsons N, Mohtadi NG *et al.*; Multicenter Arthroscopy of the Hip Outcomes Research Network. A short version of the International Hip Outcome Tool (iHOT-12) for use in routine clinical practice. *Arthroscopy* 2012; **28**: 611–8.
26. Martin RL, Kivlan BR, Christoforetti JJ *et al.* Minimal clinically important difference and substantial clinical benefit values for a pain visual analog scale after hip arthroscopy. *Arthroscopy* 2019; **35**: 2064–9.
27. McClincy MP, Wylie JD, Yen YM *et al.* Mild or borderline hip dysplasia: are we characterizing hips with a lateral center-edge angle between 18 degrees and 25 degrees appropriately? *Am J Sports Med* 2019; **47**: 112–22.
28. Martin RL, Christoforetti JJ, McGovern R *et al.* The impact of depression on patient outcomes in hip arthroscopic surgery. *Orthop J Sports Med* 2018; **6**:232596711880649.
29. Marsell R, Einhorn TA. The biology of fracture healing. *Injury* 2011; **42**: 551–5.
30. Florencio-Silva R, Sasso GR, Sasso-Cerri E *et al.* Biology of bone tissue: structure, function, and factors that influence bone cells. *Biomed Res Int* 2015; **2015**: 1–17.