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Body Weight Support Return to Running in a Patient with Musculoskeletal Hip Pathology: A Case Study

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Background and Purpose: Tendonosis is a weakened tendon, as can occur after prolonged running injuries, making return to running difficult. Stressing the tendon enough to remodel to become stronger, but not create further damage is a delicate balance. The purpose of this case report is to demonstrate how a body weight support device commonly used for patient with neurological conditions could have benefits to an orthopedic population as well. **Measures/Intervention**: A 24 year old female with right hip iliopsoas tendonosis and labral damage presented with return to running goals. The patient presented with groin and sacroiliac pain, poor right gluteus medius neuromuscular control and decreased strength, fear of pain associated with running of 6/10 and increase in pain within 30 seconds of running. The patient participated in 27 sessions of progressive body weight support running over 13 weeks. **Outcomes**: The patient was able to run for 31 minutes 29 seconds prior to increase in symptoms, she returned to her running group 1x/week, fear of pain decreased to 1/10, right gluteus medius strength improved to 98% of that of the left and neuromuscular control improved. Midpoint to final Lower Extremity Functional Scale score improved by 7 points which is just shy of a clinically meaningful change. Gait analysis revealed decreased stride length. **Conclusion and Clinical Relevance**: This intervention may be beneficial to orthopedic populations for task specific progressive loading of soft tissue to withstand forces, task specific neuromuscular re-education, fear avoidance model exposure to tasks, and progressive training. This intervention would fit within standard physical therapy addressing impairment based exercises and manual interventions. More study is needed using body weight support devices in orthopedic rehabilitation goals.

Key Words: *body weight support, running rehabilitation, tendonosis, hip*

INTRODUCTION

Running is a common recreational activity with 23.4 million American participants as of 2008 (running at least 50 times per year) and musculoskeletal pain and injury is prevalent.[1,2] Tendonosis, a weakening of a tendon after unresolved or repetitive tendonitis, can occur with prolonged injury, making returning to running difficult. This weakened tendon is vulnerable to re-injury, especially under high loading. A common approach to injury is rest and allowing unloading during recovery. However, according to Tipton et. al. an unstressed tendon/ligament will be significantly weaker at one year than one properly stressed and rehabbed, which can reach close to original strength.[3] Tipton and colleagues recommend early loading during the initial collagen synthesis and remodeling of fibers to withstand specific stresses.[3] Stressing the tendon enough to remodel it to become stronger, but not overstressing it to create further damage is a delicate balance. Eccentric loading is one treatment approach recommended for patellar tendonosis. However, considering task specificity and the complex demands of speed, power, endurance, and specific angular and positional stresses, this may not be sufficient with a return to running goal.

Running increases the ground reaction forces to 2.5-2.8 times body weight and increases with velocity.[4] With the increase in speed, also comes a decreased stance time, and thus force distribution occurs over a shorter time, resulting in a high rate of loading. Traditionally, intervals of short bouts of running followed by bouts of walking are used to progress back into running; however athletes that cannot tolerate the increase in loads in the transition from walking to running are discouraged from running. As clinicians, how do we bridge that gap between where the patient can walk vigorously without pain but running produces re-injury? A traditional approach to control the progression and maintain training in an unloaded state is underwater running. However, it may be hard to translate this to land running due to a number of factors. First, unless you have a means of systemically changing depths it is hard to progressively reload the tissues to tolerate land running. Second, the mechanics of running may be altered due to buoyancy, increasing the likelihood of forefoot strike pattern, altering task specificity if this is not the way the individual runs on land. Third, while the water allows for vertical unloading it adds horizontal resistance to move through that the tissues may not be ready for.

An alternative method for unloading during training is to use body-weight support, usually in conjunction with a treadmill. Such body weight support devices are primarily used in patients with neurological disorders for retraining walking using neuroplasticity concepts and locomotor training principles.[5,6,7] The literature contains few studies using this type of device with orthopedic patients. One randomized control trial with patients after a total hip arthroplasty who received partial body weight support treadmill training found decreased hip extension deficit, increased gluteus medius strength and EMG recruitment (peak amplitude 41.5% greater), improved walking symmetry, and decreased time before discontinuing use of crutches (3 weeks compared to 8 weeks) compared to the group with over ground gait training using bilateral reciprocal crutches.[8] A case study of a 25 year old male collegiate soccer player used body weight supported running for return to sport.[9] The patient had a history of chronic ankle sprains and was 6 weeks status post new onset ankle sprain when he participated in this 2 week study of body weight supported running and sport specific activities and was successful at returning to pain free running and soccer participation.[9] Alter G is a company that developed a body weight support treadmill using enclosed pressurized air to decrease ground reaction forces.[10] Several small studies with favorable results are reported on the corporate website.[10] Their research focusing on the hip consists of 2 case studies of young patients status post labral repair surgery.[11,12] Body weight support treadmill training was used during partial weight bearing status post operatively and progressed to running with varying amounts of body weight support to allow the patients to return to athletic competition.[11,12] The purpose of this current case study is to demonstrate how a body weight support device commonly used for retraining walking for neurological patients could also have utility and benefits to an orthopedic population of patients.

CASE DESCRIPTION

Patient Description

A 24 year old female (63 inches, 125 pounds) reported a 4 month history of right groin pain aggravated by prolonged sitting related to her graduate studies. Examination at that time indicated that the patient had a positive anterior impingement test and she underwent right hip MRA (magnetic resonance arthrogram, MRI with contrast dye injection) which revealed a truncated labrum. The injection for this procedure penetrated the right iliospoas tendon and the patient reported acute exacerbated iliopsoas symptoms following this procedure and was unable to return to running. The physician’s diagnosis was iliopsoas tendonosis in conjunction with hip labrum wear and tear.

The patient reported long standing problems with her right hip which started 6 years prior during competitive high school cross country running. She ran through ‘groin strain’ injury to complete her season and then had difficulty returning to running. After 5 years of failed attempts to this goal and intermittent rounds of physical therapy (h/o R iliopsoas strains, SI joint dysfunction, R pes anserine pain) she had returned to recreational running for about a year, completing approximately 12 miles per week prior to aforementioned exacerbated state. The patient’s goal was to return to recreational running, her history of difficulty returning to running as well as new onset iliopsoas tendon injury were factors into being a good candidate for body weight support treadmill return to running. It was also postulated whether this would help improve running gait mechanics to protect her hip.

Examination

Clinical findings at standard physical therapy onset: R groin pain medial to ASIS, deep to inguinal ligament, at worst 6/10 on a 0-10 numerical scale, (+) Thomas test on R with iliopsoas tight and tender to the palpation (psoas major and iliacus), pain with resisted hip flexion MMT, poor recruitment of R glut med with increased recruitment/compensation of TFL, SI alignment revealing R anterior innominate, L rotated sacrum, R hip ROM WNL with pain with PROM into hip flexion+IR, standing posture with increased femoral IR on R, increased lumbar lordosis, anterior proximal fibular head on R compared to L. The patient had levoscoliosis in lumbar, dextroscoliosis in thoracic as comorbid history.

Intervention

Standard physical therapy (PT) was initiated 3.5 months after MRI injection resulting in increased psoas symptoms which were unabated with rest, ice, and stretching alone. Standard PT was 1 time per week of manual therapy consisting of soft tissue mobilization/myofascial release to iliopsoas, trunk, and lower extremities, muscle energy techniques to correct SI alignment, inhibition kinesiotaping over R iliopsoas, use of SI belt for high level activities such as work outs, education in home exercise program of core stabilization and stretches (transverse abdominus, multifidus, glut med strengthening via dead bug progression, bird dog quadruped progression, plank, bridge progression, hip abduction with theraband resistance/lateral gait, stretches to psoas, quad, glut, foam roll IT band) completed 2-3x/week. 2.5 months into this intervention the patient was able to initiate body weight support return to running, deemed via manually resisted hip flexion being pain free, glut med strength 5/5 on MMT scale, and pain free walking. Once body weight support running protocol began manual therapy in PT decreased to once every 2 weeks and HEP continued at 2-3 times per week frequency.

The body weight support running intervention consisted of 27 sessions over a 13 week period (Figure 1. The training program is presented in Appendix 1). The patient used an SI belt for SI compression/support and inhibition iliopsoas kinesiotaping at baseline testing and thus the use of these factors were standardized at testing sessions to keep conditions similar, as the effects of these aides on ability to run without pain is unknown. A harness was applied that fit tightly around the core region with the bottom strap aligned with the greater trochanters. The harness clipped into an overhead body weight support device located over a treadmill. A visual display showed the number of pounds of body weight support provided. The body weight support amount was set in a static standing position. The amount of support provided at the initiation of the training was determined by the amount of support that did not alter the patient's normal running mechanics (too much weight support lifted the patient from the treadmill resulting in a forefoot striking pattern) and that allowed the patient to run without pain. For this patient, 16% of the patient's body weight was supported (20 pounds) at the start of the study and was progressed to providing less support over the course of the training sessions. Bouts of running in and out of the body weight support were alternated to resemble locomotor training principles used with patients with neurological disorders to encourage carryover of new motor control skills. The amount of stress on the tissues could be controlled by starting with small amounts of time out of body weight support and progressing this tolerance over time. Amount of body weight support, running speed, duration of bouts and total session, and frequency of sessions/weekly mileage were progressed slowly. Additionally, later in the program transferring one session a week from treadmill running to outdoor road running was incorporated into training and this was accomplished by performing run/walk intervals without body weight support. While this was not tolerated at the start of the study it was tolerated after 10 weeks of training with body weight support.

Outcome measures

The duration the patient was able to run (out of body weight support on a treadmill with no incline, at a set speed, without an increase in symptoms) was the primary outcome measure. A numeric rating scale for pain intensity in groin/pelvic region (0 being no pain, 10 being worst imaginable) was collected prior to running and at the point in which the pain increased and the running session was stopped during baseline, midpoint, and final testing. Prior to running the fear of pain associated with running was also collected using a 0-10 scale (0 being no fear, 10 being worst fear that would preclude participation in activity) as a proxy for acquiring information related to the fear avoidance model indicating prognosis as a biopsychosocial impairment, beliefs related to specific activities are important within this framework.[13]

Figure 1

Body weight support running, lite gait device with treadmill

The Lower Extremity Functional Scale outcome assessment was collected at the midpoint and at the end of the study to determine if functional improvements were perceived by the patient during this time.[14]

At the start of the body weight support running intervention 5/5 gluteus medius manual muscle test scores were reported bilaterally. Once 5/5 strength is reported with a manual muscle test further strength gains are hard to assess and hand held dynamometry was used to objectify further gains. Hand held dynamometry was used with patient in sidelying performing straight leg hip abduction to parallel to the support table and dynamometry with overpressure applied at lateral femoral condyle. Pressure was added slowly until the patient began to “give” and was no longer able to maintain static position. Three trials were performed; the average of these trials was reflected as the gluteus medius strength score.

Gluteus medius neuromuscular control was assessed with a heel tap performed on an 8 inch step as a functional measure of recruitment and kinetic chain function (Figure 2). The ability of gluteus medius to control the pelvis and knee alignment comes into play during running and is likely to affect hip joint health. An experienced physical therapist observed the patient during completion of this task for trunk, pelvis, and knee alignment, compensations, and deviation.

Video from posterior and lateral view during treadmill running was taken both in body weight support as well as out of body weight support for comparison of gait mechanics overtime. A standard speed and duration of running, and sequence of videoing were used to minimize changes associated with velocity or fatigue. In the lateral view, stride length was measured in still frame of the video from heel contact of the lead foot to toe off of the rear foot; three separate steps were measured and averaged. An object of known dimension was measured on the screen to convert size on the screen to actual dimensions. Stride length is postulated to have effects on ground reaction forces occurring at the hip.[15] From the posterior view the degree of hip adduction and pelvic Trendelenburg were measured during midstance of right and left leg during the view taken out of body weight support. Goniometric measurement of still frame video was taken and the average of three steps was taken. The degree of Trendelenburg and hip adduction could be factors insightful to dynamic neuromuscular control important to protecting the hip joint. During running training sessions no emphasis was made on altering gait mechanics.

Figure 2

Heel Tap: testing of gluteus medius neuromuscular control, grading of trunk lean compensation, level pelvis vs Trendelenburg

<u>Outcomes</u>

The primary outcome measure of this case study was the duration the patient was able to run without increase in symptoms. At the start of the return to running training this 24 year old patient with right iliopsoas tendonosis and labral pathology was able to run for 30 seconds prior to an increase in symptoms and exacerbation in the following days. After 27 sessions of progressive body weight support running training over 13 weeks, the patient was able to run continuously with the same parameters and conditions for 31 minutes and 29 seconds, stopping after a small increase in symptoms but no exacerbation in the days following. Over the course of training the patient was able to resume participation in her recreational running group one day per week. The ICF model (International Classification of Functioning, Disability, and Health) demonstrates how participation status is an important factor toward recovery.[16] Total weekly running mileage increased to 6 miles during the timeframe of the study and running frequency was progressed to 3 times a week. The patient's fear of pain associated with running went from 6/10 on a 0-10 scale to 1/10 during the study. Less fear would likely indicate an improved prognosis based on fear avoidance model data. It is unknown if improved success during training resulted in less fear or whether the decrease in fear contributed to improved results during testing, however this correlation should be studied further. From week 7 to week 14 of the study our patient's score on the Lower Extremity Functional Scale improved by 7 points (68 to 75 out of a possible 80). A minimal clinically important difference of this outcome measure has been reported as being a change by 9 points (90% CI).[14] This measure was not collected at the start of our study; if it had our overall change may have reached a clinically important difference.

Prior to the initiation of running training gluteus medius strength via manual muscle testing had reached 5/5 bilaterally. More objective data showed at midpoint (week 7) strength of right gluteus medius was 96% of that of the left, the final (week 14) strength tested at 98% of the left. From midpoint to final the right gluteus medius showed a strength gain of 36% and the left an increase by 25%. Gluteus medius neuromuscular control tested via a functional heel tap demonstrated improved dynamic control of pelvis and knee from the beginning of the study to the midpoint. These results met a plateau from midpoint to final. As measured during running gait analysis right hip adduction was consistently greater than the left and did not seem to be altered by this intervention. On average over the intervention the right hip adduction was approximately 16 degrees and the left was approximately 10 degrees. It is unknown if this is a static bony structural asymmetry or dynamic valgus with impact, however gluteus medius is purported to control dynamic valgus, and in our testing seemed to lag compared to the left only minimally. Pelvic Trendelenburg seemed slightly greater during right midstance than left midstance during midpoint (approximately average 6 degrees on right, 3 degrees on left) measuring pelvis from the horizontal with goniometry. However, identifying an appropriate landmark of measure was difficult with the baseline and final video analysis due to differences in clothing and no use of biomechanical analysis markers. Further video technical difficulties made obtaining a true stride length during baseline difficult. At midpoint stride length (heel contact of lead foot to toe off of rear foot) was on average 80 cm out of body weight support and at final average stride length was 50 cm. The outcomes are summarized in Table 1.

Table 1

Measure	Baseline	Midpoint (week 7)	Final (week 14)
Duration able to run prior to increase in symptoms at 6.0 mph on treadmill	Baseline pain 2/10	Baseline 1/10 groin/hip flexor R	Baseline 0-1/10 groin
	30 seconds	**15 min 15 seconds** (~1.5 miles)	**31.29 min** (3.1 miles)
	pain 3-4/10 R SI	pain hip flexor R 2/10	1-2/10 groin, 1-2/10 R linae alba
LEFS	NT	68	75
Pain level NRPS 0-10 best	2/10	0/10	0/10
worst	5/10	4-5/10	3/10
Fear of pain related to running	6/10	4/10	1/10
Glut Med Strength Right	MMT: 5/5	Dyna*: avg 35 #	Dyna*: avg 47.5 #
Left	MMT: 5/5	Dyna*: avg 36.5 #	Dyna*: avg 48.5 #

Heel Tap 8" step		Baseline	Midpoint	Final
Right	**Trunk**	mild compensatory trunk lean	No deviation of trunk	No trunk deviations
	Pelvis	unable to simultaneously control level pelvis	adduction of pelvis @ end but controlled	pelvic adduction at end range slightly > than L
	Knee	and knee valgus	no deviations of knee/foot/ankle	Knee remains over toe-no deviation
Left		trunk, pelvis, knee, ankle-no deviations noted	no deviations noted	No deviations noted

DISCUSSION

Limitations

Aside from cut off factors for readiness for return to running training a formal physical therapy assessment was not conducted at the start of body weight support return to running in that it was a continuation of treatment; however this serves as a limitation to the study. Initial running sessions on the lite gait apparatus was performed as a determination of feasibility of running in this device designed for walking. After it was determined as feasible, more objective data was collected at mid point and final than at the initial running, thus lacking LEFS, and dynamometry of glut med strength at start of running.

Discussion

In analysis of Appendix 1 it seems that the most frequent causes of exacerbations of symptoms during the body weight support running intervention were increases in time running out of body weight support or increases in speed. Interestingly, Grabowski et al. has shown that increasing speed increases ground reaction forces and in this case it seemed the patient struggled to handle those increases in forces, which further confirms our rationale behind starting this patient with a body weight supported running program.[4] In our intervention we modeled the protocol for use of this type of body weight support device in patients with neurological disorders for retraining walking with intervals of training in body weight support followed by carryover of new motor patterns out of support. Neuroplasticity carryovers have been demonstrated with neurological populations and therefore, for an orthopedic population it seems a good medium for task specific neuromuscular re-education striving for a similar carryover. Muscle force production needed with weight support are reduced and thus, in theory, a patient with weakness can train at a point where his/her strength is ample to produce good mechanics and then progress to increasing demands and gained functional strength, keeping good mechanics at higher loads. An orthopedic model for the use of body weight support might consist of exclusive use of body weight support with progressively less support or increases in speed, followed by integrating small exposures of running out of body weight support (with slower speeds initially) later in the intervention to encourage translation to full weight running. There are a number of variables of exercise prescription that can be manipulated to make exercise progressions affecting the loads on healing tissues. Caution must be taken to prevent increasing too many variables at the same time. As postulated earlier, this progressive loading in a task specific manner, could help healing connective tissues (i.e. tendons) become stronger and better able to withstand very specific higher loads. This progressive loading spanning 4 months seems long enough to allow for tissue remodeling to occur in response to greater demands.

Through gait analysis, especially from midpoint to final measures it seems stride length may have decreased. This may be a result of the harness fitting tightly around the level of the greater trochanter as it seems stride length was slightly less in the body weight support compared to out of body weight support. Nevertheless, even out of body weight support the final measure of stride length is less than that measured at midpoint. This may demonstrate the neuroplastcity effect that was postulated, in that changes occurring in body weight support translated to performance out of body weight support. Siverling et. al. would support this change as beneficial as "significant changes in hip and knee joint loading [were found] with a 5% or 10% increase in step rate, which was most likely due to the decreased step length (Heiderscheit)."[15] Clarke cited within Siverling seconded this concept by using accelerometry to measure loading response via peak trunk/shank deceleration and came to the recommendation that runners increase stride rate to decrease joint forces at impact loading.[15] Decreasing stride length would also decrease the amount of hip extension required in that the extra extension achieved from the transition of walking and running occurs via anterior pelvic tilt.[15] In our patient sacroiliac stability was already a problem and thus limiting excessive motion here would seem beneficial. It is also cited that "excessively extend[ing] the femur; would reasonably stress the iliofemoral ligament and anterior joint capsule[40]. In the setting of instability, disproportionate forces may be placed on the tendon of the iliopsoas, which may act as a dynamic anterior stabilizer to the hip joint [41], possibly leading to tendinopathy."[15] Future studies may consider using verbal cueing or other methods of correcting gait mechanics while in body weight support and making gait analysis a larger priority of the study.

Another potential unintended effect of the harness is added pelvic and core stability due to the mild compressive forces it creates and the need to be tight enough to not slip upward during running. This could be an aide to those in which core stability is lacking to meet the demands of running. Some upward slipping of the harness did occur during our intervention and we recommend checking the static weight setting occasionally to ensure the proper amount of support is being provided. This is also a benefit of keeping bouts short to adjust the harness or the weight support setting as the harness shifts with this type of device. It is also important to note that our weight support device had an adjustment that allows for some vertical motion to occur. This is pivotal for using this device for running since running naturally has more vertical motion than walking.

In the study conducted with patients who were post total hip arthoplasty 15% body weight support was used and remained static over the treatments.[8] Kern-Steiner et al. began with 20% support and progressed to no support over a 2 week study in the treatment of an inversion ankle sprain with return to running and soccer goals.[9] In our study we began with a similar amount of support (16%) and progressively decreased support over 13 weeks. In the case studies by Alter G 60% body weight support was initiated at 4 weeks post hip arthroscopy operation and progressed down to 5% support over an 11 week return to jogging program with the outcome of three intervals of 5 minutes running to 1 minute walking.[12] Our case study would encourage the use of body weight support, not only in patients with orthopedic conditions, but also, in patients who are not post operative with inherent weight bearing restrictions, as benefits may be made from a functional injury recovery standpoint.

Our study also highlights the emphasis on this intervention being one that occurs in combination with standard physical therapy interventions of core and hip strengthening and manual soft tissue techniques commonly used to assist in recovery, pain reduction, and correcting individualized impairments affecting return to running goals. In our study the standard PT occurred more frequently initially to ready the patient for initiation of return to running. The exercise portion then became a home exercise program and the manual soft tissue interventions occurred less frequently, as would be the case if this intervention was provided in the clinic and treatment time was allotted to it. If a patient was being seen for physical therapy 2-3 times a week it would seem feasible to initially allot one session a week (and initially due to low tolerance a small portion of one session) to this intervention and continue to work on the other physical therapy interventions. As the patient is able to progress to more frequent running sessions other interventions would be phased out as the patient improves and becomes less reliant on them. Nevertheless, the multiple interventions occurring over the time of the study could be seen as a confounding factor and a weakness of the study. Yet these interventions without body weight support running had not proven successful in returning the patient to running within a reasonable timeframe in reviewing her history.

The fear avoidance model literature supports exposing patients to activities they are fearful of in order to improve prognosis.[17,18] Patients with a history of pain with running would likely have fear of pain, these beliefs may give the patient a poorer prognosis. This concept would allow exposure to take place in a supported, "safe," environment making less pain and greater confidence of success likely.

This multi-utility would make purchasing a body weight support device more cost effective to clinics that see both orthopedic and neurologic patients as well to as the healthcare system trying to finance a large array of needed equipment. Alter G designed for orthopedic patient populations is enclosed and thus would not be feasible for neurological locomotor training which is commonly performed with lower extremity assistance and facilitation. More study is needed with this type of intervention for patients with orthopedic conditions with return to running goals.

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REFERENCES

1. Running USA's State of the Sport 2009: Part I. Available at http://runningusa.org/node/24641. Accessed March 19, 2012.

2. van Gent RN, Siem D, van Middlekoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. Br J Sports Med. 2007;41:469–80.

3. Tipton CM, Matthes RD, Maynard JA, Carey RA. The influence of physical activity on ligaments and tendons. Med Sci Sports. 1975 Fall;7(3):165-75.

4. Grabowski A, Kram R. Effects of velocity and weight support on ground reaction forces and metabolic power during running. Journal of applied biomechanics 2008; 24: 288-297.

5. Duncan PW, Sullivan KJ, Behrman AL, Azen SP, Wu SS, Nadeau SE, Dobkin BH, Rose DK, Tilson JK, Cen S, Hayden SK; LEAPS Investigative Team Body-weight-supported treadmill rehabilitation after stroke. N Engl J Med. 2011 May 26;364(21):2026-36.

6. Duncan PW, Sullivan KJ, Behrman AL, Azen SP, Wu SS, Nadeau SE, Dobkin BH, Rose DK, Tilson JK; LEAPS Investigative Team. Protocol for the Locomotor Experience Applied Post-stroke (LEAPS) trial: a randomized controlled trial. BMC Neurol. 2007 Nov 8;7:39.

7. Hicks AL, Adams MM, Martin Ginis K, Giangregorio L, Latimer A, Phillips SM, McCartney N. Long-term body-weight-supported treadmill training and subsequent follow-up in persons with chronic SCI: effects on functional walking ability and measures of subjective well-being. Spinal Cord. 2005 May;43(5):291-8.

8. Hesse S, Werner C, Seibel H, von Frankenberg S, Kappel E-M, Kirker S, Ka¨ding M. Treadmill training with partial body-weight support after total hip arthroplasty: a randomized controlled trial. Arch Phys Med Rehabil 2003;84: 1767-73.

9. Kern-Steiner R, Washecheck H, Kelsey D. Strategy of exercise prescription using an unloading technique for functional rehabilitation of an athlete with an inversion ankle sprain. JOSPT 1999; 29(5): 282-287

10. Mishra Dev K. Summary of Clinic Research Involving the AlterG Anti-Gravity Treadmill. 2011. http://www.alter-g.com/wp-content/uploads/2011/10/Clinical-Research-Summary.pdf Accessed March 19, 2012.

11. Comiskey, V. Anti-Gravity Treadmill. Case Study: Hip Labrum Repair & Microfracture http://www.alter-g.com/wp-content/uploads/2010/06/Case_Study_6_Hip_Labral_Tear_11.2009.pdf Accessed March 19, 2012.

12. Moreno, T.J. Anti-Gravity Treadmill. Case Study: Hip FAI Arthroscopy http://www.alter-g.com/wp-content/uploads/2010/11/Case-Study-14-Hip-FAI-Arthroscopy-v3.pdf. Accessed March 19, 2012

13. George, S. Z., Fritz, J. M., & McNeil, D. W. (2006). Fear-avoidance beliefs as measured by the fear-avoidance beliefs questionnaire: change in fear avoidance beliefs questionnaire is predictive of change in self-report of disability and pain intensity for patients with acute low back pain. Clin J Pain, 22(2), 197-203.

14. Binkley JM, Stratford PW, Lott SA, Riddle DL. The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. North American Orthopaedic Rehabilitation Research Network. *Phys Ther*. 1999 Apr;79(4):371-83.

15. Siverling, S., O'Sullivan, E., Garofalo, M. & Moley, P. Hip osteoarthritis and the active patient: will I run again? Curr Rev Musculoskelet Med. 2012.

16. Escorpizo R, Stucki G, Cieza A, Davis K, Stumbo T, Riddle DL. Creating an interface between the International Classification of Functioning, Disability and Health and physical therapist practice. Phys Ther. 2010 Jul;90(7):1053-63.

17. Leeuw M, Goossens ME, van Breukelen GJ, de Jong JR, Heuts PH, Smeets RJ, Köke AJ, Vlaeyen JW. Exposure in vivo versus operant graded activity in chronic low back pain patients: results of a randomized controlled trial. Pain. 2008 Aug 15;138(1):192-207. Epub 2008 Feb 1.

18. Leeuw, M., Goossens, M. E., Linton, S. J., Crombez, G., Boersma, K., & Vlaeyen, J. W. (2007). The fear-avoidance model of musculoskeletal pain: current state of scientific evidence. J Behav Med, 30(1), 77-94.

Appendix 1.

13 week Intervention of Body Weight Support Return to Running

Baseline TM walk 3.0mph 5 minutes, run 6.0 mph 30 seconds* Pain R SI, iced after session

	BWS (in pounds)	Speed	Duration	Progessions/Session Notes
Week 1				
Session 1	-20	5.0 mph	10 min	video taken to analyze baseline gait
	0	5.0 mph	10 min	
Session 2	-20	5.5 mph	10 min	Progression: freq: ↑to 2x/wk, ↑speed by 0.5 mph
	0	5.5 mph	4 min*	* R psoas pain, iced after session
Week 2				
Session 3	-20	5.0 mph	10 min	Progression: ↑volume/duration
	0	5.0 mph	2 min*/3 min	*pain in R peroneal, / indicates break was taken for
	-20	5.0 mph	5 min/5 min	rest or stretch-second / was B hip flexor stretching
	0	3.0 mph	3 min	*Total run time* 25 min, in BWS 20 min, out 5 min
Session 4	-20	5.0-6.0 mph	10 min	Progression: trial in BWS with ↑speed,
	0	5.0 mph	5 min/	↑ time out of BWS
	0	5.0 mph	1 min*/3 min	* R pes anserine pain, / hip flexor stretch, MET
	-20	5.0 mph	6 min	*Total run time* 25 min, in BWS 16 min, out 9 min
	0	3.0 mph	4 min	^ exaccerbation of psoas symptoms next few days
Week 3				skipped 1 week of training time, lack of access to BWS
Session 5	-20	5.0 mph	15 min	Progressions: continous bout ↑ from 10-15 min,
	-20	5.5 -5.7 mph	5 min	↑ speed during shorter bouts
	-20	6.0 mph	4 min	*Total time*: 24 min, in BWS 24 min, out 0 min remained in BWS due to ↑symptom last session no reports of pain during today's session
Session 6	-20	5.5 mph	10 min	Progressions: phased out 5.0mph consistently at 5.5
	0	5.5 mph	5 min	*slight R pes anserine discomfort throughout session
	-20	5.5 mph	10 min	*Total time*: 25 min, in BWS 20 min, out 5 min ^ exaccerbation of psoas symptoms next few days
Week 4				
Session 7	Missed session			
Session 8	-20	5.5 mph	10 min	Progression: ↓BWS by 2 pounds during last bout,
	0	5.5 mph	5 min/	Decreased total time by 5 min to address last flair up
	-18	5.5 mph	5 min	/ hip flexor stretch, MET Total time: 20 min, in BWS 15 min, out 5 min
Week 5				
Session 9	-15	5.7 mph	10 min	Progressions: ↑ speed by 0.2 mph, ↓ BWS
	0	5.7 mph	5 min	Total time: 15 min, in BWS 10 min, out 5 min
Session 10	-15	5.7 mph	10 min	Progressions: total duration ↑ by 5 min from last session

	0	5.7 mph	5 min	at current parameters
	-15	5.7 mph	5 min	Total time: 20 min, in BWS 15 min, out 5 min Total distance: 1.85 miles
Week 6				
Session 11	-15	5.7 mph	10 min	Progressions: None
	0	5.7 mph	5 min*/	*L psoas discomfort, SI discomfort post run
	0	3.0 mph	8 min	/stretched hip flexor, adductors, quads pre and post Total run time: 15 min, in BWS 10 min, out 5 min
Week 7				
Midpoint Run Test	TM 0	6.0 mph	15 min 15 sec	Progression: ↑ time running out of BWS Mild increase in R hip flexor pain, no ↑ following day Pt reports fear of pain the next day was limiting
Session 12	-15	5.0 mph	10 min	Video taken to analyze mid point gait
	0	5.0 mph	10 min	Total time: 20 min, in BWS 10 min, out 10 min
Week 8				
Session 13	-15	5.7 mph	10 min	Intent to ↑ freq this week, moderated session for this
	0	5.7 mph	5 mim	1.6 miles total
	-15	5.7 mph	2 min	Total time 17 min, in BWS 12 min, out 5 min
Session 14	-15	5.7 mph	10 min	
	0	5.7 mph	5 min	1.9 miles
	-15	5.7 mph	5 min	
	0	3.0 mph	5 min	Total time 20 min, in BWS 15 min, out 5 min
Session 15	-15	5.7 mph	10 min	Progression: ↑frequency/ weekly total mileage (4.8 miles)
	0	5.7 mph	4 min*	* mild R pes anserine pain 1.3 miles
	0	3.0 mph	1 min	Total time: 14 min, in BWS 10 min, out 4 min
Week 9				
Session 16	-15	5.9 mph	10 min	Progression: ↑ speed by 0.2 mph
	0	5.9 mph	5 min	2 miles
	-15	5.9 mph	5.5 min	Total time: 20.5 min, in BWS 15.5, out 5 min
Session 17	-15	5.9 mph	10 min	Progression: ↑ time/distance (4.5 min/ 0.45 miles)
	0	5.9 mph	5 min	2.45 miles
	-15	5.9 mph	10 min	
	0	3.0 mph	2 min	Total run time: 25 min, in BWS 20 min, out 5 min
Session 18	-15	5.9 mph	5 min	Progression: ↑ weekly mileage 14% (5.45 miles)
	0	5.9 mph	5 min	1 mile Total run: 10 min, in BWS 5 min, out 5 min
Week 10				
Session 19	Road Run 0		30 min 43 sec	Progression: TM→Road Terrain change
	run 3 min walk 1 min intervals			3 miles Total run time: 21 min (3 min x7)

Session 20	-15	6.0 mph	10 min	Progression: ↑speed by 0.1 mph
	0	6.0 mph	5 min	2.5 miles
	-15	6.0 mph	10 min	Total time: 25 min, in BWS 20 min, out 5 min
Week 11				
Session 21	Road Run 0		33 min	Progression: None, 2 min overall time ↑ out of BWS
	run 3 min walk 1 min intervals			on road, accomidated for by ↓ speed
	last run bout 5 min			Total run time: 23 minutes
Session 22	-13	6.0 mph	10 min	Progressions: ↓ BWS by 2 pounds
	0	6.0 mph	5 min	2.26 miles
	-13	5.8 mph	5 min	
	0	5.8 mph	3 min	Total time: 23 min, in BWS 15 min, out 8 min
Session 23	-10	6.0 mph	8 min	Progression: weekly mileage ↑15% (0.5 miles) 6.06 miles
				↓ BWS by 3 pounds this session
				0.8 miles
Week 12				
Session 24	-10	6.1 mph	6 min	Progression: ↑ speed by 0.1 mph, low volume for
				tolerance of ↓BWS ↑ speed
Session 25	-10	6.0 mph	10 min	Progression: ↑duration of run @ current BWS
	0	6.0 mph	5 min	
	-10	6.0 mph	6 min	Total time: 21 min, in BWS 16 , out 5 min
Week 13				
Session 26	Road Run 0		31.35 min	Progression: 1 run bout ↑by 1.5 min
	run 3 min walk 1 min intervals			* R pes anserine pain/discomfort post run
	last run bout 6.5 min			3 miles Total run: 24 min out of BWS
Session 27	-10	5.0 mph	10 min	Video taken to analyze final gait
	0	5.0 mph	10 min	Total time 20 min, in BWS 10 min, out 10 min
Week 14				
Final Run Test	TM 0	6.0 mph	31.29 min	Mild increase in R hip flexor pain, no ↑symptoms
				following day 3.1 miles
				Pt reports fitness was a limitor to continous run

* SI belt used in all running sessions, inhibition psoas kinesiotaping used in most sessions
*TM=treadmill, BWS=Body weight support, R=Right, L=left MET=muscle energy technique for SI alignment
*most sessions stretched hip flexors prior to session, iced groin post session