Result of the Biodex Stability System on Proprioception and Balance Following an Achilles Tendon Repair: a Case Report

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ABSTRACT

Objective: The purpose of this case report was to discuss the use of the Biodex Stability System (BSS) as an early intervention modality in the physical therapy treatment of a person post Achilles tendon surgical repair. ***Case Description:*** The participant was a 41 year old man who sustained a traumatic left Achilles tendon rupture while playing non-competitive squash. Orthopedic evaluation revealed a palpable defect over the left Achilles tendon insertion, a positive Thompson test, and hyper dorsal flexion sign indicating a complete Achilles tendon rupture. Upon post-operative physical therapy evaluation the participant was noted to have increased pain, edema, and ecchymosis, and decreased active range of motion (AROM), balance, proprioception and function. ***Methods:*** The participant was started on a traditional rehabilitation program to address all impairments, and increase function through active and passive stretching, progressive resistive exercises, gait training, balance exercises and BSS activities. The BSS was introduced into the program at week three to supplement balance and proprioception training. His progress was measured through use of the visual analog scale (VAS) for pain, AROM, circumferential girth measurements, functional strength, and VAS for quality of life and function. ***Outcomes:*** The participant displayed a 47% improvement in left dorsi/plantar flexion AROM, 62.5% improvement in strength, reduction of 2 points on the VAS, a greater than 60% reduction in edema, and a 50% increase in quality of life as compared to initial post-surgical visit. Balance and proprioception were also notably improved as indicated by the increasing difficulty of tasks on the BSS. ***Discussion:*** It was found that a combination of the BSS and traditional rehabilitation resulted in very positive physiological and functional gains in a male status-post Achilles tendon surgical repair.

INTRODUCTION

According to Greek mythology, Achilles was a half-God warrior viewed to be the most handsome and powerful soldier in the Trojan War. The story asserts that Achilles' body was completely impervious to any harm with the one notable exception of his heel, his only vulnerability. This vulnerable spot eventually led to Achilles' death by poisoned arrow.[1] This myth led to the eventual naming of the Achilles tendon (AT) which, like its mythical background, is known for being the most vulnerable tendon in the human body to rupture. As the largest tendon in the body, rupture of the AT most commonly occurs during sporting events where the tendon is stretched forcefully and eccentrically past its normal tensile capability causing the tissue to be torn.

Though the tendon is very large and usually very strong, it is still susceptible to severe injury. Sport activities that involve pushing off the foot quickly, making sudden and quick cuts or diagonals, and direct trauma such as being kicked or stepped on in the posterior foot are just a few of the most common mechanisms of injury for AT. According to Parekh et al,[2] the increasing prevalence of AT ruptures can be attributed to the increased number of social or sedentary athletes who start out with physical activity that is beyond their skill level.

Although there is no current rate of incidence reported for the United States, incidence in Finland shows 18 in 100,000 individuals rupture their Achilles tendon yearly. Most injuries occur as a result of racket sports such as badminton, tennis, and racquetball.[3] In addition to involvement in high intensity sports, risk factors associated with AT rupture include individuals who are between 30-40 years of age, extended use of antibiotics and glucocorticoids, direct injections of corticosteroids into the tendon, and a long standing history of Achilles tendinopathy or tendonitis. It has been shown to be 20 times more likely to occur in male athletes than female

athletes. This rupture is very debilitating and painful as the AT plays an integral part in smooth gait pattern and ambulation. Even after treatment, people usually experience notable deficits in gastrocnemius and soleus strength as well as a decrease in overall functional ability.[2]

According to Bressel et al,[4] there are two research derived theories for AT ruptures: a degeneration theory and mechanical theory. The degeneration theory states that the collagen and cellular matrix of the musculotendinous unit changes over time by recurring micro-traumas which in turn weaken the tendon, and predispose it to acute rupture. The mechanical theory states that a perfectly healthy tendon can rupture as a result of an uncontrolled mechanical force being placed on the tendon resulting in spontaneous tendon rupture.

Once a rupture occurs the person will experience a significant disruption in normal function and sensation surrounding the involved ankle. Like any large tendon in the body, the AT contains a large number of integral mechanoreceptors that are responsible for transmitting proprioceptive input back to the brain for balance, kinesthesia, and ankle joint preservation.[5] According to Lee and Lin,[5] proprioception is a simultaneous understanding, by the human body, of the combined kinesthesia of a joint and its static joint position sense. Proprioception is necessary for proper neuromuscular motor planning as well as dynamic joint stability, both of which contribute to balance and joint stability in activities of daily living and athletics. The loss of proprioceptive integrity is very hard to regain, especially after surgical repair of the ruptured tendon, and requires extensive therapy.

Although there are several treatment techniques that can be utilized for AT ruptures, the most common and most recommended treatment is immediate surgical repair of the tendon. Although there is no consensus among orthopedic surgeons as to the most appropriate surgical technique, there is a push to move to a minimally invasive endoscopic technique, as open repair

techniques are more susceptible to adhesion formations, infection, and re-rupture. This surgical method, although still fairly invasive, is usually necessary to retrieve the retracted tendon and reattach the two ends via suture.[6] As with any surgical repair the area is at risk for complications during the healing process. Because of this risk, post-surgical rehabilitation tends to remain fairly conservative and cautious. It is also imperative that the area is not completely immobilized for too long as scar tissue and atrophy of the surrounding stabilizing muscles can present their own very unique and difficult challenges. According to Ozkaya et al,[6] aggressive physical therapy beginning 4-6 weeks post-surgery is appropriate to increase the functional recovery of the tendon and decrease the risk of scar tissue and contracture formation.

Aggressive physical therapy often includes early range of motion, weight bearing, balance activities, and proprioception exercises as soon as possible in accordance with the recommendation of the physician. According to the protocol developed by Westlake Orthopedic Spine and Sports clinic,[7] phase 1(0-2 weeks post-op) is a conservative stage. The person is frequently reminded that this is a crucial healing phase and their foot should remain predominately immobilized and any weight bearing should be discouraged initially. This phase is utilized for pain management, cryotherapy, and incision management. It is very important for the physical therapist to be aware of the high risk of infection that may occur in this phase.

During phase 2 (2-6 weeks post op) the person is encouraged to begin active range of motion on their own while the therapist assists them in gentle passive range in all planes. It is also important for the individual to begin weight bearing on the affected foot during this stage. Initially the person should only perform partial weight bearing starting at 30% of their body weight and steadily build up to full weight bearing as tolerated. Utilization of crutches, cam walker boots, cane, or a roll-about may be helpful for safety.

During phase 3 (6-8 weeks post-op) the individual is encouraged to progress to full weight bearing, and proprioception and balance exercises are introduced into the therapy program. These exercises can include activities like single leg stance, dynamic balance activities on challenging surfaces, marble pick-up, seated BAPS board rotations, and cup walking. Some strengthening exercises such as theraband resistance exercises, stationary bicycling, and double leg heel raises should be slowly introduced as tolerated. The person should progress as tolerated throughout the rest of their duration of therapy, gradually increasing the difficulty of each activity until the person can safely return to work, sport or activities of daily living.[7]

This traditional rehabilitation protocol has a good functional outcome and the majority of people are able to return to pre-injury level within 8-12 months post repair. Early weight-bearing programs were found to have a more beneficial outcome for range of motion and function than programs emphasizing immobilization, with no increased incidence of re-rupture.[8] However the most common complaint at the end of the rehabilitation protocol was related to an ongoing struggle with poor proprioception, and balance of the affected leg.[8]

Since proprioception and balance are the most difficult skills to regain long term, therapists are beginning to use new unique equipment to enhance these skills earlier. One such system is the Biodex Stability System (BSS). The BSS is a machine that utilizes an unstable surface, capable of moving freely in both the anterior-posterior and medial-lateral axes, to help individuals build and progress their dynamic balance and proprioception. The resistance of the platform on which the person stands, can be varied or restricted in direction according to the goals of the treatment session. In addition to the adjustable force-plate platform, the BSS has a computer screen attached to the platform that depicts a visual representation of the activity being performed. This visual component of the equipment can be changed to require the person to

complete different tasks such as hitting a moving target, guiding a pointer through a maze, or simply maintaining static balance, by simply shifting their weight on the platform. The visual aspect of these tasks help link physical and mechanical input from the unstable surface with the matching visual input on the screen and helps promote increased balance, proprioception, and kinesthesia in the involved extremity.[9] It has been found that use of simultaneous visual imagery during balance activities greatly improves proprioception in other lower extremity injuries, such as knee and ankle ligament sprains, and joint replacement surgery.[10]

Use of the BSS has also been shown to decrease the amount of time for an individual to return to pre-injury level of function in regards to proprioception and balance. Not only can it be used to train and improve balance and proprioception throughout rehabilitation, it can be used as an objective outcome measure to test and measure progress throughout therapy.[10,11]

Currently in the literature there are many articles that discuss the importance of regaining proprioception and balance as soon as possible following a lower leg injury or surgery as well as a number of appropriate protocols as to how to accomplish this task.[10-13] Akhbari et al[14] found that after 4-weeks of stability training on the BSS rehabilitation program in individuals with functionally unstable ankles, significantly increased peak and onset latency of the ankle stabilizing muscle contraction were noted as measured by EMG. This effectively increased their efficiency in ankle protection during athletics. There is also a number of articles explaining the success the BSS has had in assisting with increased lower extremity balance, proprioception, and fall prevention. For example, Srivastava et al[15] report that the BSS force platform with visual feedback is an appropriate rehabilitation technique for balance and fall prevention in individuals who have had a stroke and who are still living with deficits. Furthermore the BSS helps improve

overall locomotor skills in this population. Currently there is little to no literature directly exploring the BSS as an appropriate intervention tool for post-operative AT repairs.

The purpose of this case report is to discuss whether the Biodex Stability System, when used as an early intervention in the physical therapy treatment post AT surgical repair, helps promote improved balance and lower extremity proprioception in a 41 year old male post Achilles tendon repair. The outcomes of therapy will be discussed.

METHODS

Case Description

The participant was a 41 year old man who sustained a traumatic Achilles tendon rupture while playing non-competitive squash at his gym. He was 5 foot, 10 inches tall and weighed 190 pounds. He worked in marketing, traveled frequently and described himself as a "recreational athlete". He had two young children, enjoyed squash and ran 4-5 miles 2 or 3 times a week prior to his injury. He denied smoking and only drank socially. Immediately following the injury the participant was seen at a local emergency room and splinted, which did improve his pain and ambulation. He was then referred to an orthopedic surgeon in our company for orthopedic follow-up and evaluation. The orthopedic doctor's initial evaluation revealed a well-appearing man in no acute distress, alert and oriented times three, with overall joint function and strength within normal limits with the exception of the left gastroc-soleus complex. Review of systems revealed that he was in exceptional health and all vital signs were normal. He was not on any long-term medications and had only been taking ibuprofen for dealing with the pain of the current injury. He refused stronger pain medications at the emergency room stating that he prefers to stay away from strong medications whenever possible. Past surgical history includes an appendectomy at the age of 17.

Upon detailed inspection of involved left ankle and foot complex, it was noted there was a palpable defect over the left Achilles tendon area approximately 3 centimeters above the insertion point. There was only mild edema in the area and minimal discoloration and bruising. There was, however, a positive Thompson test sign and hyper dorsal flexion sign both indicative of an Achilles tendon complete rupture. Upon further testing it was found that he had good ankle dorsiflexor, invertor, and evertor strength; normal neurosensory integrity distally; and normal dorsal pedal and posterior tibial pulses. The participant reported his overall pain was 6/10 on a visual analog scale.

After discussion of the options for treatment, the participant expressed interest in surgical repair which was performed two days later on March 19, 2009. The surgical procedure was an open procedure where the torn end of the Achilles tendon was sutured to its distal insertion using #2 fiber looped sutures and the appropriate tension of the tendon was tested compared to the right unaffected side.

The participant was seen in the physical therapy clinic for an initial visit 2 weeks post surgery. He presented to therapy on two crutches in a locked boot with a 2-layer heel wedge to maintain slight plantar flexion. Via observation it was noted that the participant ambulated with two axial crutches, independently, using a swing through gait pattern. He reported that, though he avoided them when he could, he did not have any problem ascending or descending stairs. He was also independent in sit to and from stand transfers from chairs and onto treatment tables. The participant reported he had returned to work and was able to move around his office building without difficulty but he had no plans to travel until he could move around an airport easier. He stated his biggest challenge in daily activities was showering but he could manage it without assistance. Other activities have not been a problem. He reported his at rest post-op pain was

4/10 on the visual analog scale. Ecchymosis was increased on left but the incision appeared to be healing well with no sign of infection and main limitations included increased pain and swelling, decreased overall range of motion, and decreased function of left ankle/foot. Active and passive range of motion (ROM) of bilateral upper extremities, left hip and knee were all within normal limits and moderately limited at left ankle/foot. Post-op edema was measured via trans-malleolar and metatarsal-phalangeal girth measurements and there was found to be increased edema of left ankle/foot compared to right unaffected side (See Table 1 for specific AROM, girth, strength and VAS measurements). Manual muscle testing for strength was not measured at initial visit to avoid aggravation of healing tissues.

Outcome Measures

In order to track the progress of the participant several outcome measurements were taken on a regular basis (approximately every third physical therapy session) to help quantify his progress. The first of these measures is a visual analog scale (VAS) to objectify his pain level. The participant was asked "On a scale of 0-10, 0 being no pain and 10 maximum pain, how would you rate your pain currently". VAS pain scales have a high test-retest reliability (ICC=.99) and good validity and are appropriate for tracking changes in pain throughout treatment.[16]

Goniometric measurements were taken to track AROM throughout the interventions. Goniometric measurements were taken using the techniques presented by Reese and Bandy.[17] Goniometric measurement has also been found to have a favorably high test-retest reliability (ICC=.99) and construct validity (ICC=.98-.99) making it also an appropriate outcome assessment to be utilized throughout the treatment process.[18]

To measure edema girth measurements were taken every time AROM was measured in order to maintain a consistent measurement schedule. Two different areas were measured; transmalleolar girth and metatarsal-phalangeal (MTP) girth. Transmalleolar girth is performed by measuring the circumference of the ankle with the tape measure laying over both malleoli. The MTP girth is performed by measuring the circumference of the ankle with the tape measure lying over the distal heads of the first and fifth metatarsal of the foot. Currently, there is no specific statistics to back up these specific methods of ankle girth measurement but similar lower extremity girth measurement studies have been performed and the results have been favorable. For example, for the figure-of-eight girth measurement of the ankle both the intertester ICC and the intratester ICC are equal to 0.99, meaning that this test has a very good reliability and its use in clinical application is encouraged.[19]

To measure balance gains throughout treatment, the level of difficulty achieved during various BSS dynamic balance challenges was monitored. The BSS has a favorable test-retest reliability of ICC=.82 which makes it a reasonable tool for documenting progress as well as challenging the patient's balance and proprioception.[20]

Muscle strength was unable to be assessed consistently via manual muscle testing due to surgical restrictions so we opted to measure overall gastroc-soleus complex strength by asking the participant to perform first double leg and then single leg heel raises when he was cleared for full weight bearing by the doctor. The distance of the heel off the floor the participant was able to achieve was measured with a ruler and documented and tracked. There are no concrete statistics to back up this method currently in the research.

The participant's function was noted through subjective conversations as reported weekly. The participant has very specific goals for therapy and was very upfront regarding

where he would like to be at, functionally, at the end of therapy. For example, the participant would like to be able to walk comfortably through an airport when traveling for his job, and would like to be able to play with his 4-year old daughter pain free. These goals are not necessarily quantifiable in a scientific spectrum but can be still be tracked throughout the plan of care. Needless to say, there is no concrete statistics to back up this method in the current research.

Finally, the participant was asked one VAS quality of life question to help gauge his overall satisfaction with progress throughout his treatment. The question was "How would you rate your overall function, on a scale of 1-100 with 1 being terrible function and you are very unhappy with your progress and 100 being back to full normal function and you are very happy with your progress?". Though this is not a quality of life measure that has been studied in the literature, as mentioned above VAS scales are very effective in practice.[16]

Evaluation

Upon evaluation at the first physical therapy session (approximately 2 weeks post surgery) it was found that the participant was limited in function as a result of several impairments resulting from the injury and subsequent surgery. The participant expressed difficulty being able to keep up with his 4 year old daughter as a result of poor and unsteady gait. The participant was unable to participate in squash and running as a result of poor gait, pain, scar formation, decreased ROM, and strength. The participant has been unable to return to work up to this point due to being unable to travel and ambulate comfortably through airports as a result of poor gait, pain, and muscle fatigue.

Prognosis/Goals

Despite the above mentioned impairments and functional limitations this participant had good rehabilitation potential due to his overall good health, successful surgery, and strong motivation to improve and get back to pre-injury activity level. When asked about his personal goals for physical therapy the participant expressed desire to return to his pre-injury level of physical activity and looked forward to being able to move around well again so that he could play with his very active daughter. Long term physical therapy goals included: 1) The participant will be able to ambulate independently, full weight bearing, without boot or crutches, community distances, within 6 weeks. 2) The participant will have decreased pain to <2/10 on VAS with activity within 4-6 weeks. 3) The participant will have decreased swelling around the ankle by >50% within 4 weeks. 4) The participant will have increased dorsiflexion and plantar flexion ROM to 10^{o}-40^{o}, respectively, within 4-6 weeks. 5) The participant will be able to perform active double leg heel raise, at least 2 inches off floor, with minimal discomfort within 4-6 weeks. 6) The participant will be able to perform single leg balance on affected left foot, for 30 seconds, within 4-6 weeks. 7) The participant will be able to safely play with and carry his 4 year old daughter within 6-8 weeks, as reported by him. 8) The participant will be able to jog recreationally, pain free for one mile, within 16 weeks.

Plan of Care

The participant was started on a rehabilitation program to address all impairments, functional limitations, and goals for therapy. Rehabilitation focused on increasing function by improving range of motion, ambulation, balance, and proprioception as well as decreasing pain, swelling, and patient apprehension. The interventions were divided into three phases. The purpose of Phase I was to decrease pain and swelling and promote proper healing of the surgical site. The purpose of Phase II was to promote active ROM, proprioception and weight bearing as

tolerated, while the purpose of phase III was to promote sport specific activities, full ROM, strength, and balance.

Range of motion was encouraged as soon as possible and he was instructed to perform them 3-5 times a day or as often as tolerated for the full duration of PT treatment. Ambulation was also encouraged as soon as possible, in accordance with the doctor's recommendation, and included gait education with and without assistive devices. Balance exercises such as double and single leg stance, were initially only performed in the clinic, with supervision, to make sure that all exercises were being performed safely but, upon approval by the physician, was also added to the participant's home exercise program. Finally, each PT session was concluded with 15 minutes of vasopneumatic cryotherapy to assist in pain and swelling reduction. See Table 2 for details of the general plan of care.

In addition to standard exercises, the BSS was introduced to the participant at week three to begin balance and proprioception training as soon as possible. He completed several tasks on the BSS system that included side to side weight shifting, postural stability, randomized control, limits of stability, and a maze. During side to side weight shifting, he coupled both a visual representation of weight distribution as well as percentages denoting how much of his total weight was being shifted.

Postural stability is a static balance activity that challenged the participant by asking him to keep the "dot" as close to the center point while the platform is made unstable. Randomized control asked the participant to keep the "dot" within the center of a moving circle while the platform was simultaneously made unstable. The difficulty of this task was changed by increasing or decreasing the size of the moving circle or by increasing or decreasing its speed.

Limits of stability asked the participant to shift their weight on the unstable platform to move their "dot" to touch a series of spaced out circles that blink one by one making the participant adapt their weight shift to reach each circle. The difficulty of this task was changed by increasing or decreasing the distance between the blinking circles.

Finally the maze asked the participant to move their "dot" around a maze configuration following blinking circles. The difficulty of this task was changed by increasing or decreasing the difficulty of the maze.

In addition to changing the purpose of each task, the difficulty of each task was changed by increasing or decreasing the level of instability of the platform. Graded on a scale of 12-1, difficulty is increased as the numbers decrease, with 12 being the least unstable and one being the most unstable. Some of the tasks end when the task is completed (limits of stability, maze) while others are ongoing for as long as the participant or evaluator deem necessary (weight shifts, postural stability, randomized control).

OUTCOMES

Prior to the intervention, the participant presented with pain, edema, decreased AROM, decreased strength , decreased proprioception, decreased quality of life, and function limitations. After 16 weeks of physical therapy, improvements were noted in all categories above, see Table 3. AROM of full left ankle plantar flexion to full dorsi-flexion improved from a 50% deficit at initial visit to only a 3% deficit as compared to uninvolved side. Strength, as represented by single leg heel raises, improved from a 100% deficit at initial visit to a 37.5% deficit at discharge, as compared to uninvolved side. And quality of life, as reported by the patient improved from a 80% deficit at initial visit to a 30% deficit at discharge.

Balance and proprioception gains are best indicated by the steady increase in difficulty of the BSS games/exercises as represented by Table 4. Functionally he reported that he returned to a full traveling work schedule within 5 weeks of the beginning of physical therapy, based on his ability to ambulate comfortably through the airport without an assistive device. He was able to successfully wean off the CAM walker boot at week 6 of the intervention. The participant reported that he was able to play normally with his 4 year old daughter, including ambulating while holding her, by week 7 of the intervention. The functional goal still being pursued, upon discharge, was to jog recreationally, one mile on a flat surface, pain free. At the time of discharge the participant reports that he was only able to jog a quarter mile at a time comfortably but was still able to complete 3-4 miles of a walk/job combination 3 times a week.

DISCUSSION

The participant did see noticeable improvements and met most of the goals set forth by the treating team and the participant himself. As mentioned above, he displayed a 47% improvement in dorsi/plantar flexion AROM putting him very nearly within his own normal limits as compared to the uninvolved ankle. He displayed a 62.5% increase in strength, as represented by single leg heel raises, compared to the initial assessment. These improvements were a direct result of the successful implementation of the traditional plan of care, the BSS program, as well as his persistent motivation to get better. The participant also reported a 50% increase in quality of life as compared to the initial post-surgical visit. He elaborated that his quality of life had improved because his overall functional ability had improved noticeably. Rissanen et al[21] reported that overall improvement of functional ability is directly related to quality of life improvement following lower extremity surgical interventions. It is believed that

these activities will continue to improve as the participant continues to re-integrate into his normal activities and routines as well as continue to heal from the invasive surgery.

Steady gains were also made in the fields of balance and proprioception. This was represented by the change in task and steady increase in difficulty and time he was able to successfully complete on the BSS. The participant was found to be fairly competitive regarding his scores and ability which no doubt aided his desire to and ability to succeed on the different BSS tasks. It is believed that his frequent use of the BSS during his therapy sessions helped him rebuild his proprioceptive feedback from his left ankle, foot, and knee that were damaged with the injury, allowing him to have increasingly improved balance and function.

Additionally, the participant was able to meet most of the goals. His pain decreased to only 2/10 on VAS with prolonged activity, he had a greater than 60% reduction in edema, improved AROM to within his normal limits, and increased single leg heel raise strength as to maintain the position for greater than 30 seconds. Again, these improvements were a direct result of the successful implementation of the traditional plan of care, the BSS program, as well as his persistent motivation to get better. Functionally, the participant reported that he was able to ambulate comfortably through the airport by week 5, was able to ambulate without an assistive device by week 6, and was able to play with his daughter by week 7.

The only goal that was not completely met that was originally set forth related directly with the participants ability to run. The initial goal set forth was that the participant would be able to jog recreationally, pain free for one mile by discharge from therapy. The participant reported that he was only able job a quarter mile at a time at discharge, but that he was able to complete a 2-3 mile walk/jog combination 2-3 times per week. He reported that his limitation to jogging a greater distance was the “nagging pain” (a 2/10 on VAS) and his overall decrease in

physical endurance. The reasons for his difficulty with running were discussed and it was explained that, while his overall gait pattern was better than it was at his initial post-op evaluation, it was still not as efficient as it was prior to the injury. He would need to practice and build-up his running ability again. This is also true of his overall endurance, as his inability to be as active as normal over the past 16 weeks had significantly decreased his athletic endurance. In addition, it was explained that the breakdown and re-alignment of the large amount of scar tissue surrounding the surgical site would take much longer to heal into the most efficient functional alignment, and this process would limit his ability to run normally.

Limitations

The plan of care was created with the participant's individual goals in mind as well as the equipment readily available in the clinic. To maintain ethical practice, every appropriate treatment option to improve overall function was considered and utilized to achieve these goals. This means that it was unclear how much the BSS program exclusively aided this participant. It is clear that the BSS was in no way detrimental to him and that proprioception and balance did indeed improve at a very reasonable rate. Without having a comparison sample that compared the combined traditional and BSS therapy with an exclusive BSS intervention group and an exclusive traditional therapy group, it is difficult to decipher the true contribution that the BSS made to improvement of function.

Additionally, the BSS program created for this participant was by no means regimented and adjustments to the difficulty of each test phase were made solely based on how the treating therapist during each session perceived his progress. It is unclear whether he would have had better or worse results if the degree of difficulty were more closely monitored and regimented to increase at previously determined treatment phases. It is not clear whether the participant would

have had quicker results if the treatment team had advanced the difficulty more frequently forcing him to adapt more quickly or if this would have set him further back. This and other similar questions still surround this topic. The results of this report indicate that the BSS very likely contributed to improvement of function in a very positive manner but it is clear a more in depth analysis study must be conducted to determine just how much the BSS benefits persons after Achilles tendon repairs.

It is undeniable that striving to obtain the highest level of proprioceptive and balance ability is extremely important to any person's overall functional ability. The means to this goal is the most variable aspect of this process. As we already know, there are countless exercises, games, and interventions available to patients and therapists to optimize these results and it is usually up to the therapist/physician team to come up with the most appropriate plan of care for each person. So, are the positive results, and the timeframe to achieve these results, improved enough with the BSS to warrant the overall cost of purchasing the BSS for a physical therapy clinic? According to the Biodex company's website (http://www.biodex.com/rehab/rehab.htm) the BSS retails at about $11,170.00 which does not take into account continuous warranty coverage, maintenance and calibration fees and software packages that are required expenses on a yearly basis.[22] Needless to say, the average physical therapy clinic might find this to be an unneeded expense given the alternative cheaper options to obtain the same goal, albeit in a possibly slower time frame. For example, use of a dyna disc or BAPS board for dynamic balance activities require the same type of postural and physical response with the exception of the visual component. With the assistance of a therapist who presents a dynamic target for reaching during these activities, the visual component can be created in a more rudimentary format. More

concrete evidence may be needed to justify the purchase of such an expensive piece of equipment for the average physical therapy clinic.

Not every person will benefit from the BSS. The nature of the machine is to create an unstable surface that will challenge the ability of the participant to maintain their balance as well as re-learn how to control their body's natural reactions to an unstable surface in order to obtain a goal. The BSS is can be used with a large population of patients regardless of age, gender, or singular diagnosis but it may prove to be too difficult or intimidating for some people which may subsequently create an unnecessary risk to both the patient and their progress. For example, the BSS may not be appropriate for someone with multiple diagnoses or joints affected. An individual who presents with distal neuropathies as a result of other neurological or disease processes may be deemed unsafe to be on the BSS or may be found to benefit greatly from it. The same goes for someone who may have multiple musculoskeletal pathologies occurring at once or a cardio-pulmonary concern that may be aggravated by increased anxiety, apprehension, or effort. In these cases it is imperative that the therapist talk to their patient, understand possible limitations and be aware of the risk versus benefits of utilizing the BSS prior to implementing this intervention.

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Table 1: Initial AROM and Girth measurements taken at first PT session.

	VAS Pain 1-10	Dorsiflex Active	Plantarflex Active	Inversion Active	Eversion Active	Trans-malleolar Girth	MTP Girth	SLHR*
Right	0/10	4^o	44^o	26^o	10^o	28.6 cm	26 cm	4.0 in.
Left	6/10	-13^o	23^o	17^o	9^o	29.8 cm	27.1 cm	N/T
*SLHR= Single leg heel raise.								

Table 2: General plan of care broken down into phases.

Phase	Goal/Purpose	Common Exercises
I	Control post-op pain and swelling	AROM- dorsi/plantar/ inversion/eversion: 3 sets of 10 reps each.
0-4 weeks	Protect healing structures	Gentle gastrocnemious stretching: 3 sets of 30 sec.
	Maintain Dorsiflexion ROM to 10*	Light Theraband resistance exercises into plantar flexion: 3 sets of 10 reps.
		Gait training with bilateral crutches with TTWB.
		Recumbant bike: 10 min at moderate pace with boot.
		Biodex weight shifting to 30% body weight.
		Vasopneumatic cryotherapy: 15 min with max pressure.
II	Regain full ROM.	Gastrocsoleus complex stretching: 3 sets of 30 sec.
4-8 weeks	Normalize gait pattern in walking boot without assistive devices.	Ankle inversion/eversion/dorsiflexion progressive resistive exercises.
	Increase ankle strength.	Double leg --> single leg heel raises: 3 sets of 10 reps.
	Progress to full weight bearing.	Gait training without assistive devices: cup/cone walking.
		Recumbant bike: 10 min at moderate pace with boot.
		Biodex stability and proprioception games/exercises.
		Balance activities: double and single leg balance, balancing on high density foam: 3 sets of 30 sec.
		Vasopneumatic cryotherapy: 15 min with max pressure.
III	Increase ankle strength.	Weight bearing ankle exercises: 3 sets of 10 each.
8-16 weeks	Increase cardio endurance	Single leg dynamic stability exercises: 30 times each.
	Begin pre-injury activities	Walk/Jog on treadmill or eliptical: 10 min.
		Sport specific dynamic activities: 3 sets of 10 reps each.
		Biodex high difficulty proprioception games/exercises.

Table 3: AROM and Girth measurements taken at the end of each month of PT treatment.

	VAS Pain 1-10	Dorsiflex Active	Plantarflex Active	Inversion Active	Eversion Active	Trans-malleolar Girth	MTP Girth	Functional MMT	VAS QOL 1-100
April	4/10	0^o	40^o	25^o	10^o	29.2 cm	26.3 cm	<>	20/100
May	3/10	6^o	35^o	27^o	12^o	29.0 cm	27.1 cm	DLHR* ~2 in.	40/100
June	2/10	10^o	35^o	30^o	10^o	28.2 cm	26.0 cm	SLHR** ~1 in.	60/100
July	2/10	11^o	36^o	30^o	11^o	28.0 cm	26.0 cm	SLHR** ~2.5 in	70/100

* DHLR= Double leg heel raise.

** SLHR= Single leg heel raise.

Table 4: Biodex Stability activities performed throughout PT intervention.

Phase	Date	Level of Difficulty	Type of Activity	Duration
I	4/9/2009	6	Postural stability	3 min
	4/13/2009-4/15/2009	4	Postural stability	3 min
	4/21/2009-4/23/2009	5	Postural stability	3 min
II	4/28/2009-5/4/2009	4	Postural stability with light perturbations.	4 min
	5/8/2009	4	Postural stability	4 min
		4	Side to side wt shifts	4 min
	5/18/2009-5/21/2009	7	Randomized control	3 min
		7	Limits of stability	2 min
	6/3/2009-6/5/2009	6	Randomized control	3 min
		6	Limits of stability	3 min
	6/8/2009	5	Randomized control	3 min
		5	Limits of stability	3 min
III	6/11/2009	5	Limits of stability	3 min
		8	Maze- easy	3 trials
	6/15/2009-6/18/2009	5	Limits of stability	3 min
		7	Maze- easy	3 trials
	6/24/2009	7	Randomized control	3 min fast
		6	Maze- moderate	3 trials
	6/29/2009-7/2/2009	6	Randomized control	3 min fast
		6	Maze- moderate	3 trials
	7/8/2009-7/13/09	6	Randomized control	3 min fast
		5	Maze- moderate	3 trials