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CASE REPORT

REHABILITATION OF AN ELITE OLYMPIC CLASS SAILOR WITH MCL INJURY

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ABSTRACT

Background. A paucity of literature exists related to the care of sailing athletes with knee injuries. Hiking has been examined to describe its demands, but comprehensive sources for rehabilitation recommendations based upon evidence are non-existent. Guidance and understanding of human motion are key to success in the face of limited evidence.

Objectives. Impairments and functional restrictions were identified in a Finn Sailor with MCL (medial collateral ligament) injury. A regimen of strengthening, conditioning, and functional benchmarks was devised to progress a sailing athlete from non-functional to sailing specific training and the athlete's competitive goal. Coordination with a strength/conditioning professional was key to maintaining the athlete's competitive level.

Case description. The patient is a 21 year old Finn class sailor with an acute MCL knee injury eight weeks prior to a world class and national ranking event. Following evaluation, treatment with sailing-specific functional testing coincided with training/conditioning. Common-sense functional tasks were used to replicate demands of hiking and balancing to evaluate readiness for sailing/training.

Outcomes. Return to sailing with protection occurred in 12 days, unrestricted training and competition were achieved prior to the ranking event at 8 weeks.

Discussion. Mobility, stability, control, strength, and endurance are not only crucial to performance in the boat, but sailors need to avoid pitfalls in the boatyard while safely transitioning from land to water. Competitive calendars may not allow for textbook protocol, therefore, all goals should be strongly correlated with functional ability, athlete confidence, and performance needs.

Key Words. medial collateral ligament, sailing, hiking

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INTRODUCTION

Many intricacies exist within the sport of sailing, and the rehabilitation of a sailing athlete following injury must take these intricacies into account. Research on sailing injuries is in its infancy, despite the fact that the sport of organized sailing has been around for over 150 years. Little is known about the biomechanics, physiology, and predictive performance indicators within this sport. Rehabilitation professionals are limited in their evidenced-based knowledge and traditionally base treatment on personal experience or insight from the patient.

Limited evidence-based current sailing literature exists describing the requirements on the body during a hiking maneuver. Hiking is a technique used by sailors to generate righting moments to counteract the heeling forces of the boat. A heeling force is generated by the wind across the sails causing the boat to tip away from the direction of the wind. Hiking is performed by the sailor placing his/her feet under toe straps within the boat, and leaning their body out over the side of the boat (beam) in increments to counter the heeling force. Forceful hiking is typically performed during various parts of races where the heeling forces are the greatest or during windy conditions. Examples include such instances of upwind, or crossing the starting line, when attempting to overtake an opponent, or when trying to avoid being overtaken. In some classes of sailboats, the sailor can spend as much as 94% of the race in a hiking position[1] *(Figure 1)*. Hiking has been described as a quasi-isometric contraction of the knee extensor and the hip flexor muscles.[2] Hiking is considered quasi-isometric due to small amplitude changes in the force production to counteract the changing waves. Strong isometric and eccentric muscle production is required to perform this task and maximal quadriceps muscle torque values are required to hike successfully.[3]

One issue that presents itself during rehab and training for this population is the inability to simulate hiking on dry land. Problems occur due to the fact that on dry land the unpredictability of the waves is not able to be reproduced. Prolonged isometric training tends to be poorly tolerated by most individuals and truly does not replicate the hiking requirements due to the lack of the need for small amplitude adjustments. Prolonged isometric contractions are believed to restrict blood supply during the contraction and this resulting ischemia rapidly causes fatigue of the muscles.[2] The fatigue of these muscles typically causes the sailor to isolate the vastus lateralis muscle while hiking on the water which can lead to a lateral tracking patella and resultant patella femoral knee pain. To reduce these risks, both education on turning the feet outward to increase the workload on the vastus medialis and endurance training have been anecdotally recommended.[4] This positioning has been discussed in vastus medialis facilitation in rehabilitation and conditioning literature, but not studied via eletromyographic studies of hiking. Cross training activities such as circuit training, running, cycling, indoor rowing, and explosive lower extremity strengthening all have been implemented in an attempt to increase hiking performance. However, no consensus exists on which of these activities is optimal for increasing hiking performance nor is there agreement on an appropriate dry land test which can be used to predict and monitor hiking performance.[5]

Figure 1. *Athlete in Finn dinghy in hiking position*

Studies have been performed examining the muscle requirements during hiking moments and have indicated that the quadriceps, iliopsoas, and abdominal muscles are the main muscles involved in this technique.[6,7] Research has also been successful in describing the quadriceps muscle torques required for this hiking maneuver and shows that individuals who hike have greater quadriceps muscle torque values in comparison to other trained individuals.[3,5] These values have been determined in the Laser sailing class with replication of positional demands of the athlete in relationship to the boat, and recreating angles of performance on hiking simulators. The hiking simulators in the literature correspond with actual Laser dinghy dimensions. It has been shown that during hiking, an elite sailor can produce maximal quad torque values up to 305-325 Nm.[8] The Laser class athlete manages a smaller, lighter boat, with less sail area. Therefore Finn athletes in larger, heavier dinghies with greater sail area are logically larger heavier athletes that may be required to produce more force than the values seen in the current literature.

Additional factors that are involved in the rehabilitation of an elite sailing athlete include movements within

the boat and transfers on and off the vessel. While racing, these athletes also need to reposition themselves to the other side of the boat with ease and speed. This requires the ability to squat fully while moving laterally under the swinging boom, during turns through the wind. Full hip and knee range of motion are required as well as exceptional balance and coordination. This position involves moving laterally while in a fully flexed position and good stability of the knee is essential. This motion also occurs under adverse circumstances including a wet and continually moving surface due to the activity of the waves. The requirements of this motion, along with the unpredictability of the waves, put the athlete at risk for injury if he or she does not possess adequate range of motion, strength, proprioception, and balance.

Besides training and racing, another stress on Finn class sailors is transferring on and off of the boats. These transfers include at least one moving surface and can possibly involve two with a moving boat and a floating dock. When these surfaces are wet, or if conditions are windy, this transfer can possibly pose the greatest risk for sailing related injuries. Often times there are large height differences between the dock and the boat as well. Beach launching of a sailboat presents shifting support, wave action, conflicting visual and proprioceptive information, and uneven surface negotiation by the athlete. These transfers require sudden adjustments to counteract the changing surfaces and the presence of inclement weather further increases the demands on the sailor. Many sailors anecdotally report that the transfer on and off the boat represent a great risk of injury.

The purpose of this case study is to present the progression experienced by an elite Finn class sailor in his recovery from medial collateral ligament (MCL) injury. The demands of the sailing athlete are unique, and this case can serve as a potential guide in helping other sailing athletes with similar injuries. The goals of rehabilitation for an athlete dealing with the conditions unique to sailing include: 1) pain free maximal quadriceps muscle contraction; 2) full resolution of edema; 3) full range of motion of the knees and hips; 4) increased joint stability, balance, and proprioception; 5) maintain fitness for sailing; and 5) return to pain free sailing, especially hiking, at the previous competitive level. These outcomes were measured respectively via visual analog scale (VAS), palpation and observation, standard goniometric comparison to the uninvolved knee, and clinical and functional performance outcomes reported by the athlete following sailing activities. A Lower Extremity Functional Scale (LEFS) was applied retrospectively, to clarify the state of the athlete for the purposes of this article.

CASE DESCRIPTION

The subject described in this case was a 21 year old college student who competes Finn class sailboat at a world class level. At the time of injury he was 6'2", 216 pounds. The Finn sailboat is a single person heavy dinghy, 14 feet (4.28m) in length, which has a 115 square foot (10m2) sail and a 4 foot 10 inch (1.51m) beam to beam measurement.

While training eight weeks prior to an international competition, the athlete sustained a left medial collateral ligament (MCL) injury resulting from a severe valgus force to his knee. This injury occurred on November 23, 2005 when the athlete was returning his dinghy to shore at dusk. His left leg broke through a damaged portion of the dock caused by Hurricane Wilma that hit South Florida a month earlier. His leg was instantaneously entrapped within the dock in a vertical position at the knee and his momentum caused his trunk and upper body to fall to his left. This created a violent valgus force at the knee. The athlete had to be lifted out of the dock and was unable to immediately bear weight through is left leg due to medial knee pain.

Initial Emergent Care Days 1-4

He was promptly taken to the emergency room (ER) where x-rays were performed and found to be negative. Patient was discharged with axillary crutches, wearing a straight knee splint, and advised to not bear weight on his left leg. Due to the injury occurring the day before Thanksgiving, Performance Enhancement Team (PET) members were not able to be contacted by phone until two days after the injury. At the time of initial phone contact the athlete described being unable to fully extend the knee or flex past approximately 45 degrees. Pain was reported as 7 out of 10 on a Visual Analog Scale (VAS) at rest. An evaluation was desired, however due to the holiday, the patient was not able to receive a full clinical evaluation until the following Monday, five days post injury. During this interim, he was instructed to apply ice to the left knee for at least 20 minutes every hour, elevate the injured leg, perform quadriceps sets, and attempt to reestablish full extension via prone hangs and unsupported passive knee extension. Heel slides were used to

reestablish flexion range of motion (ROM).

Day 5 Initial Evaluation and Treatment Examination Results

The initial evaluation was performed on November 28 by a physical therapist PET member of the athlete's sailing team. At this time, informed consent was obtained for treatment and use of clinical findings for potential publication. The evaluation showed that his left knee was negative for any posterior cruciate ligament or anterior cruciate ligament laxity, signs of meniscal tearing, or lateral collateral ligament laxity. Left knee ROM showed that the patient was able to move his knee from 0 – 125 degrees with pain at end range flexion. During left MCL testing, grade II laxity was shown at 30 degrees of flexion with no laxity when tested in 0 degrees *(Table 1)*. Strength testing of the left lower extremity revealed 4-/5 for both the quadriceps and hamstrings muscles while the vastus medialis muscle activation was fair. Other findings included moderate effusion and severe tenderness over the distal MCL below the joint line. Lower extremity function score (LEFS) for this time was 26/80. The results of this initial evaluation were discussed with team physicians, and the patient was advised to continue rehabilitation. At the beginning of rehabilitation, the patient subjectively expressed significant frustration after being told the risks of attempting to sail in his current condition.

Treatment Days 5-11

Treatment began immediately after the initial evaluation. Stationary cycling, closed kinetic chain exercises, mobility, balance, and flexibility exercises within the pain free range were started. The athlete was also fitted with a neoprene brace with double upright rigid supports. The brace was initially worn for all activities including during sleep; bathing was exempted from brace use. The progression is generally summarized in Tables 2 through 5. Patient was also given a personal TENS unit to help with pain control. Conventional TENS parameters of symmetrical biphasic square waveform 100Hz frequency, 100 microsecond pulse duration, intensity above sensory threshold but below motor threshold were used as needed. Electrodes were placed directly over the painful site along the MCL.

During the first two weeks of treatment, while pain persisted with activities of daily living (ADL), ice was used prior to any exercise bout. The patient started out using a stationary bike performed with the seat high to decrease

Table 1. *Ligamentous Laxity Scale*

Grade III >10mm Medial joint line opening to valgus stress
Grade II 6-10mm Medial joint line opening to valgus stress
Grade I 1-5mm Medial joint line opening to valgus stress

Table 2. *Rehabilitation Progression (Acute Management Pre-Evaluation)*

Acute Management (Days 2-4)
RICE 20 minutes per session, multiple sessions daily
Quadriceps Setting
Unsupported Extension
Prone Hangs
Knee Flexion active range of motion within limits of pain
Non weight bearing on axillary crutches as advised by emergency room

painful knee flexion. To increase knee extensor strength, patient performed lateral step downs, squats, and lunges with focus on eccentric control of the quadriceps. Pain-free workloads were set. The exercises were pain-free by athlete report due to icing prior to bouts. For balance work, the patient practiced single leg stance on compliant surfaces with eyes open and closed *(Figure 2)*. Patient was also instructed on comprehensive abdominal exercises to increase core strength and support.

Figure 2. *Athlete performing stabilization exercises on compliant surface with perturbations applied*

Table 3. *Rehabilitation Progression Days 5-12*

PAIN/EFFUSION MANAGEMENT
Conventional TENS p.r.n.
RICE p.r.n.
Bracing

GAIT
Non weight bearing (NWB) progressed to full weight bearing (FWB)
NWB swing through gait advance to 3 point pattern weight bearing as tolerated (WBAT) on involved lower extremity from day 5 until day 6
WBAT with one axillary crutch until day 7
d/c crutch to FWB on day 7 in brace

ENDURANCE
Warm-up cycling progressed to full aerobic sessions (10 min progressed to 30 min)

STRENGTH
Closed-Kinematic Chain Progressive Resistive Exercises(PREs) and Open-Kinematic Chain (OKC) quadriceps in pain-free ROM

Exercise	Sets x Reps	Rest	Load	Pain-free limit	Progression
Unilateral Step-downs	2x8	45s	--	8 reps	3x12 30s rest
Body Weight Squat	2x12	120s		12 reps	2x14 90s rest
OKC Leg Extension	2x8	60s	48 lbs	8 reps	3x14 30s rest 60lbs
Leg Press	2x12	120s	110lbs	--	2x20 90s rest 140lbs

OKC Hamstring and Hip PREs

Exercise	Sets x Reps	Rest	Load	Pain-free limit	Progression
Bilateral Leg Curl	2x8	60s	36lbs	8 reps	3x14 30s rest 48lbs
OKC Hip abduction/ adduction/flexion/ extension	3x8	60s	96lbs	--	--

MOBILITY/FLEXIBILITY
Patellar mobilization
Flexion active assistive range of motion (AAROM)
Hamstring Quadricep Iliopsoas Gastroc/Soleus stretching

NEUROMUSCULAR RE-EDUCATION
Standing balance/proprioception on non-compliant surface for 2 bouts in 20s with 120s rest
Progressed to compliant surface training for 3 bouts in 30s with 90s rest

CONDITIONING
Resume upper body and core program

Day 12 Re-evaluation and Treatment

Examination Results

Findings from patient re-evaluation on day 12 post-injury showed decreased MCL laxity from grade II to I, full ROM of the left knee, and quadriceps muscle strength of 4/5. Minimal tenderness to palpation elicited pain 3/10 on a VAS scale. No pain was reported with ADLs. Trace effusion was palpable. The LEFS score at this time was 55/80.

Treatment Days 12-21

Prior to sailing, dry-land hiking exercises with increasing levels of instability were used to determine if the athlete could tolerate the activity *(Figures 3, 4)*. Additionally, ball toss on half-sphere balance trainer in the half squat position, single leg stance ball toss, jogging, and single leg extension with maximal resistance were all challenges successfully cleared prior to sailing. During the following week of treatment, the patient began sailing again with some pain during hiking. Limits to sailing activity were based upon wind conditions, because higher wind speeds are directly proportional to hiking demands.[9]

Day 22 Re-evaluation and Treatment

Examination Results

The next re-evaluation took place on day 22 post-injury. The patient at this time had been sailing for about 10 days having experienced only mild discomfort during hiking without an increase in symptoms. MCL laxity remained at grade I with trace effusion, vastus medialis tone was nor-

Table 4: *Rehabilitation Progression Days 12-22*

PAIN/EFFUSION MANAGEMENT
RICE p.r.n

SAILING-SPECIFIC
Simulated Hiking
2 bouts 1 min
1 bout 2 min
Progressed to 3 bouts of 3 min by day 22

ENDURANCE
Warm-up cycling progressed to full aerobic sessions (10 min progressed to 30 min)

STRENGTH
Closed-Kinematic Chain PREs and OKC Quadriceps in pain-free ROM

Initial Exercise	Sets x Reps	Load	Rest	Progression	Sets x Reps	Load	Rest
Unilateral Step-Downs	--	--	--	Walking Lunges	3x12	--	30s
Body Weight Swat	--	--	--	Squats on _ balance ball	3x12	--	90s
Standard Squat with resistance	3x14	45lbs	90s	Same exercise	3x14	110lbs	90s
OKC Leg Extension	--	--	--	Same exercise	3x14	88lbs	30s
Leg Press	--	--	--	Same exercise	3x14	160lbs	90s
Bilateral Leg Curl	--	--	--	Same exercise	3x14	90lbs	30s
Unilateral Reverse Leg Curl on ball	2x12	--	120s	Same exercise	3x14	--	30s
OKC Hip abduction/add uction/flexion/ extension	--	--	--	Same exercise	3x14	108lbs	60s

MOBILITY/FLEXIBILITY
Maintain patellar mobility
Maintain flexion ROM
Hamstring Quadricep Iliopsoas Gastroc/Soleus stretching

NEUROMUSCULAR RE-EDUCATION
Single leg balance advance to Eyes open for 3 bouts in 60s with 90s rest
Eyes closed for 3 bouts in 40s with 120s rest
Standing balance/proprioception progressed to unilateral compliant surface training with medicine ball catch/throw or trainer perturbation for 3 bouts in 30s with 90s rest

CONDITIONING
Reintroduce jog on treadmill 5min progressed to 15 min
Progress to running basketball court lengths x 10 @ 50% full speed
Upper body and core program
Agility quick feet ladder progression for 3 bouts in 20s with 20s rest
Reintroduce road bike progressed to 45min

ON WATER
Sailing while braced in light conditions progressed to moderate conditions (light to moderate hiking demand 3-14 knots windspeed[8,9])

Table 5: *Rehabilitation Progression Days 22-60*

PAIN/EFFUSION MANAGEMENT
RICE p.r.n

SAILING-SPECIFIC
Simulated hiking
5 bouts of 5, 4, 3, 2, 1 min
Upper body pulling exercises in hiking position
Cross body cable rows
Unilateral rows
Mainsheet pulls overhead

ENDURANCE
Warm-up cycling progressed to full aerobic sessions (10 min progressed to 30 min)

STRENGTH
Closed-Kinematic Chain PREs and OKC Quadriceps Exercises

Exercise	**Sets x Reps**	**Load**	**Rest**
Body Weight Step Ups 30min	3x12	--	45s
Weighted Walking Lunges	3x12	60lbs	30s
Weighted Walking Lunges with Twist	3x12	50lbs	30s
Body Weight Squats on _ balance ball	3x12	--	90s
Standard Squat with resistance	3x14	180lbs	90s
OKC Leg Extension	3x14	120lbs	30s
Unilateral OKC Leg Extension	3x14	75lbs	30s
Leg Press	3x14	360lbs	90s
Bilateral Leg Curl	3x14	120lbs	30s
Unilateral Reverse Leg Curl on ball	2x14	--	120s
OKC Hip abduction/adduction/flexion/extension	3x14	108lbs	60s

MOBILITY/FLEXIBLITY
Maintain patellar mobility
Maintain flexion ROM
Hamstring Quadricep Iliopsoas Gastroc/Soleus stretching

NEUROMUSCULAR RE-EDUCATION
Single leg balance advance to Eyes open for 3 bouts in 60s with 90s rest
Eyes closed for 3 bouts in 40s with 120s rest
Unilateral compliant surface training with medicine ball catch/throw or trainer perturbations
Progressed from 2.2lb to 8.8 medicine ball for 3 bouts in 30s with 90s rest
Squats on _ stability ball with medicine ball catch/throw
Progressed from 2.2lb to 8.8 medicine ball for 3 bouts in 30s with 90s rest

CONDITIONING
Road Bike progressed to 60min
Running — Treadmill progressed to 30 min
Progress to sprinting — 75m x 3 @ 100% full speed
Upper body and core program
Agility quick feet ladder progression — 3 bouts 35s 90s rest
Side shuffling @ 50% full speed — 3 x 10m Bilaterally 15s rest
Progressed to full speed — 3 x 10m Bilaterally 30s rest
High knees — 3 x 10m 30s rest
Kick the Can — 3 x 10m 30s rest
Plyometrics-line jump forward — 3 x 15 contacts 90s rest
Progressed to forward + lateral line jumps — 6 x 15 contacts 15s rest

ON WATER
Sailing in all conditions progressed from moderate to heavy conditions (moderate hiking demand progresses to heavy in greater than 14 knots windspeed[10,11])
d/c bracing for all activities as of week 5

mal, and quadriceps strength had increased to 4+/5. No pain on palpation or with training was reported by the athlete. LEFS scale at this time 77/80.

Treatment Days 22-42

Following re-evaluation the patient progressed through three more weeks of rehabilitation. In these three weeks, the patient's exercises focused on maintaining ROM, increasing strength and stability to his knee, as well as increasing endurance. For knee stability, strength, and improved agility this athlete performed body weight squats on half-sphere stability trainer, walking lunges with twists, single leg bridges, step-ups on a 2.5 feet high platform, and forward/lateral line jumps. He performed road biking and running/jogging work to improve endurance during the last three weeks. Accelerations and lateral running/side shuffling were introduced to increase power and agility as well as to increase stability of the knee.

Figure 3. *Hiking on a stable supporting surface*

Figure 4. *Hiking on an unstable supporting surface*

OUTCOME

Following the end of his rehabilitation, the patient's left knee was completely resolved as of January 23, 2006. His LEFS score was 80/80. In the ranking event, the sailor was the highest placed American team member in the Finn Class. The athlete was able to resume sailing without any limitations and currently ranks in the top echelon in world standings for his class. In August, 2008 he represented the United States in the Finn Class during the Beijing Olympics. He won the silver medal in the regatta. No adverse knee events have been reported by the athlete to date.

DISCUSSION AND CONCLUSION

The biggest problem when developing a rehabilitation program for sailing is the lack of evidence and research on the subject. Currently very little is known about the mechanics, muscle requirements, body stresses, and treatments of injured sailors. Near-maximum quadriceps muscle torques are required for hiking and these sailors have increased quadriceps muscle torque values compared to other trained athletes.[3,5,8] Hiking activity in land-based environment and patient reports of confidence on moving surface balance training were used as benchmarks for return to the dock and hiking on water. Standardized functional testing (single-leg hop, lateral power hops, etc.) were abandoned since these tests did little to replicate demands of actual sailing. Time waiting to actually meet a passing score on standard bilateral lower extremity comparisons would have likely delayed the athlete from being ready for the team qualifying event.

Well after the resolution of this case, Tan et al[5] reported that in normal dinghy sailors (Laser class), three minutes of simulated hiking on a dynamometer actually correlated well ($r > .80$) with sailing performance. Anthropometric measures, abdominal muscle endurance, vertical jumps, cycling time to exhaustion, or sustained isometric quadriceps muscle endurance tests all were weaker correlates ($r < .60$). This information supports the use of actual hiking or simulated hiking to determine functional capability in dinghy sailing.

Studies need to be performed to better identify treatment programs and exercise regimens that directly relate to increased performance on the water. In the absence of such data, the therapists involved followed the golden rule of "listen to your patient," and his knowledge of sailing and guidance was a fundamental component in his own success.

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