Isotonic and isokinetic strength training in an international level triathlete after a calf muscle strain injury – a case study

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Headline

Calf muscle strain injuries is common in both team and endurance sports such as triathlon (Fields & Rigby, 2016; Green & Pizzari, 2017; Korkia, Tunstall-Pedoe, & Maffulli, 1994). It has been recommended that rehabilitation of such injuries should be a progression from isometric to isotonic and isokinetic concentric and eccentric strengthening (Baoge et al., 2012). However, documentation (i.e. force and excursion) of exercises targeting the calf muscles (i.e. calf raises) during the course of the rehabilitation is missing. Such information might aide the clinical decision making and facilitate individualized progressions.

Aim

Present a case study consisting of an unloaded to isotonic and isokinetic calf strengthening program using robotic resistance of a patient (international level triathlete) with a calf muscle strain (grade 3A).

Methods

Case description. The patient is a male international level triathlete who during running uphill felt an acute deep pain in the left calf after 40 minutes. Following the injury the patient did not run and consulted a sports medicine physician after three weeks as he was unable to walk without pain. An ultrasound examination was performed revealing a partial tear measuring 10 to 12 mm with 3-4 mm thickness located at the distal aponeurosis of the left medial gastrocnemius, which is compatible with a microlesion at this level (Figure 1). This injury can be considered a small muscle tear (type 3A) (Mueller-Wohlfahrt et al., 2013). The prognosis was good and the athlete was expected to return to competition after six to eight weeks. In the subsequent four weeks treatment followed the P.O.L.I.C.E. (protection, optimal loading, ice and elevation) principle (Bleakley, Glasgow, & MacAuley, 2012). Specifically, ice, unloaded open chain range of movement exercises to standing partial weight bearing (hand support) bilateral calf raises were performed.

At seven weeks only small improvements had been made and he was re-evaluated by another professional. A new ultrasound evaluation was ordered, which revealed a presence of a small hypoechoic-homogeneous area of 10 mm remains, with a maximum thickness of 3 mm, next to the soleus-gastrocnemius aponeurosis, as scarring due to a previous injury (Figure 2). On a zero to ten Numeric Rating Scale (NRS) the athlete reported 0/10 walking and 10/10 if attempting running. The athlete was fearful of loading the posterior calf (fear avoidance).

Training program. Since no systematic load progression had been implemented this became the focus of the training program. In fact, it has been recommended that during the repair phase a progression from isometric to isotonic and isokinetic strengthening without pain should be done (Baoge et al., 2012). Furthermore, early onset of recovery has been found to be advantageous in muscle strain injuries with pain <5/10 on NRS on range of motion exercises (Bayer, Magnusson, Kjaer, & Tendon Research Group, 2017). Unfortunately, Bayer and co-authors did not identify maximum pain-level for their strength training program (Bayer et al., 2017). Thus, we conducted a strength training program (from isometric to isotonic and isokinetic) with a more conservative pain-level (NRS<3/10).

The primary focus first of the first sessions (week eight) was to address fear avoidance using isometric bilateral calf raises (Table 1). During week nine bilateral calf raises was progressed to four sets per day and isometric unilateral calf raises were introduced. In week ten these exercises were completed pain-free and the training program was progressed to concentric unloaded calf raises. In week 11 and 12 unilateral calf raises was introduced as the athlete could complete bilateral calf raises pain free (0/10 NRS). External loading was first introduced in week 13 using robotic resistance (1080 Quantum, 1080 Motion Nordic AB, Stockholm, Sweden). Specifically, loaded unilateral calf raises (8 kg) was introduced using a belt attached to 1080 Quantum with the speed limit set to 0.2 m·s-1 (Figure 3). The excursion of the movement was quantified to determine if the load was too much, or if the athlete was fatigued (< 9 cm excursion). During the following weeks (14 to 17) both the concentric and eccentric load was kept at 8 kg for a total of five sessions. At the end of week 17, the athlete returned to running as unilateral loaded calf raises were pain-free. Then, from week 18 to 22 the 1080 Quantum synchro (includes a bar of 27 kg) with an additional 18 kg external load was used. This to ensure low acceleration into the concentric speed restriction. An overview of the training program is provided in Table 1.

Tests. Force measurements were obtained from all training sessions, however specific isokinetic force tests (concentric speed limit: 0.1 m.s-1) were done on three occasions from unilateral calf raises when external load was tolerated. Average peak and average force from the first set (five repetitions) of the different loaded conditions were calculated. Specifically, repetitions with highest and lowest average force (N) were removed and the mean of the three remaining repetitions used as outcome measurement. Testing sessions were conducted as follows: test 1 (week 13: with belt using 3, 6, 9 and 12 kg load), tests 2 (week 18: with bar (27 kg) using 1080 Quantum Synchro with additional load to of 6,12, 24, 30 and 36 kg) and test 3 (week 27, same as test 2). Symmetry of force measurement was documented with positive numbers indicating greater force output from the right leg. External load was different from test 1 to test 2 and 3 with the latter two presented in Table 2. Graphi-

Table 1. Training program

Exercise	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13-18	Week 18-22
Bilateral calf raise	Isometric (15 reps (10 sec/3 sets/daily)	Isometric (15 reps (10 sec/1 set/daily). Concentric (15 reps/2 sets/daily)	Isometric (15 reps (10 sec/1 set/daily). Concentric (15 reps/2 sets/daily)	Isometric (15 reps (10 sec/1 set/daily). Concentric (15 reps/3 sets/daily)			
Unilateral calf raise (unloaded)		Isometric (15 reps (10sec/2 sets daily)	Isometric (15 reps (10sec/3 sets daily)	Isometric (15 reps (10sec/2 sets daily) Concentric (15 reps/3 sets/daily)	Isometric (15 reps (10sec/2 sets daily) Concentric (15 reps/4 sets/daily)		
Unilateral calf raise (loaded)						Isotonic and isokinetic training (0.2 m/s; 8 kg) (5 reps, 2 sets, 6 sessions). Isokinetic test 1 (week 13) and test 2 (week 18)	Isotonic and isokinetic training (0.2 m/s; 45 kg) (5 reps, 2 sets, 4 sessions). Isokinetic test 3 (week 27)

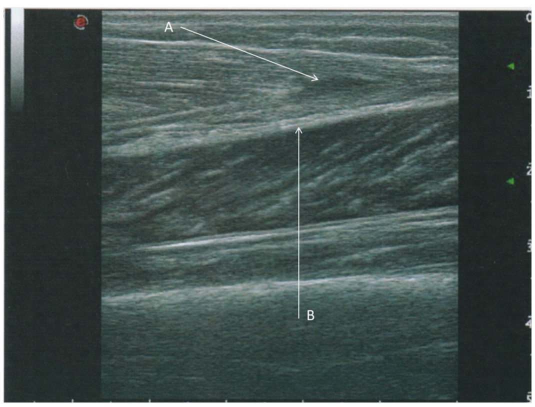

Fig. 1. Ultrasonography of injury site after 3 weeks. Site of injury described by the physician (A) and aponeurosis (B).

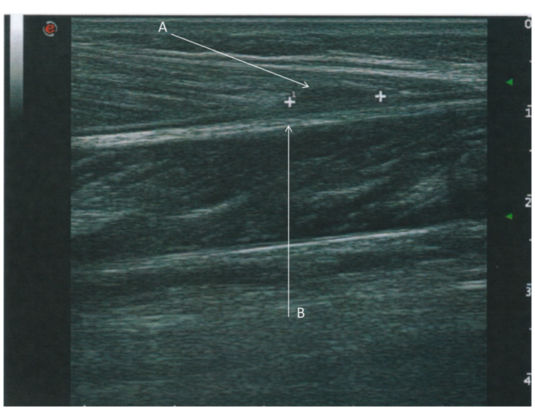

Fig. 2. Ultrasonography of injury site after 7 weeks. Site of injury described by the physician (A) and aponeurosis (B).

cal presentation of force development of all tests are presented in Figure 4.

Results

The athlete returned to jogging in week 10 when calf raises without pain could be completed. Then, running was introduced at week 17. The athlete was an active decision maker in the return to running process as he was apprehensive in generating force through the left leg (psychological readiness of Step 2 of the Strategic Assessment of Risk and Risk Tolerance (StARRT)), and not willing to take the risk of missing an upcoming important international competition (Step 3 StARRT) (Shrier, 2015). Tolerance to external load and the ability to generate force in unilateral calf raises was an important factor in this decision making process. Specifically, from week 18 to 27 force measurements improved for both left (18.9 to 23.5%) and right calf raises (8.8 to 19.5%) (Table 2). Furthermore, asymmetry decreased from test 2 (0.4 to 9.1%) to test 3 (-3.4 to 4.2%). The athlete returned to competition at week 24 where he finished 9th in an international triathlon qualifier without any report of calf pain. At three months follow up no recurrent injury has been reported.

Fig. 3. Set-up of unilateral calf raise using 1080 Quantum (illustration photo)

Table 2. Isokinetic tests with side differences and changes

Test	Test 2 Average force Left (N)	Average force Right (N)	Symmetry (%)	Test 3 Average force Left (N) (% change)	Average force Right (N) (% change)	Symmetry (%)
Unilateral calf raise (33 kg)	440	480	8.3	523 (18.9)	522 (8.8)	-0.2
Unilateral calf raise (39 kg)	455	497	8.5	562 (23.5)	549 (10.5)	-2.4
Unilateral calf raise (45 kg)	526	528	0.4	623 (18.4)	631 (19.5)	1.3
Unilateral calf raise (51 kg)	567	621	8.7	699 (23.3)	708 (14.0)	1.3
Unilateral calf raise (57 kg)	618	680	9.1	789 (21.8)	824 (15.1)	4.2
Unilateral calf raise (63 kg)	697	713	2.2	849 (21.8)	821 (15.1)	-3.4

Discussion

To our knowledge this is the first case study to use robotic resistance device in the training program for an athlete with a partial calf muscle tear (Type 3A) (Mueller-Wohlfahrt et al., 2013). This case provide insight of how robotic resistance can be used to provide different types of resistances (isotonic and isokinetic), and document progression of force output during a training program. In the future such information may be used to guide return to sport decision-making process in patients with calf muscle injuries.

The use of robotic resistance allowed us to quantify calf raises (force and excursion) during testing and training sessions. This information was used to progress the training program and guide return to sport. Specifically, the inability to reach the excursion requirement (> 9 cm) is indicative of excessive external loads or fatigue if occurring later in a set. This criteria was not set based on absolute reference values, but normalized to the athlete based on excursion of a full bilateral calf raises with low loads, as foot length will influence excursion.

Both symmetry and magnitude of force measurements improved. Symmetry of isokinetic force measurements of different movements are commonly used as return to sport and competition criteria (Eriksrud, Ghelem, & Cabri, 2019; Orchard, Best, & Verrall, 2005). However, in this case study symmetry was not used as a criteria for return to running or competition. At the time of return to running the observed asymmetry ranged from 0.4 to 9.1%, which reduced to -3.4 to 4.2 after return to competition. Thus, the observed levels of asymmetry might not have impacted return to running and competition. We have since followed the athlete for three months without any reoccurrence. Thus, it might be that improved strength had a greater effect on the successful outcome as the return to competition took long time based on initial prognosis. Specifically, greater improvements were observed for the injured (range: 18.9 to 23.3%) than the non-injured leg (range: 8.8 to 19.5%) (Table 2).

However, these improvements are based on the latter stages of the training program as changes from test 2 to test 3 are presented (Table 2). The reason for not including test 1 in Table 2 is that different external loads were used. Different external loads can impact the time or excursion the exercise is truly isokinetic, since portions of the excursion will always be used to achieve the set concentric speed limit (Cabri, 1991). Consequently, as greater external loads are used smaller portions of the excursion is subject to the isokinetic stimulus, as a greater excursion is used to accelerate to the set speed limit. In combination with "hitting the speed limit" with an impact peak (deceleration) isokinetic force measurement comparisons between different external loads should be done cautiously. Based on current results and clinical experience lower concentric limits have since been introduced to 1080 Quantum to increase time under tension and decrease the influence of different external loads. Also, consistent isokinetic tests should be applied throughout the training program.

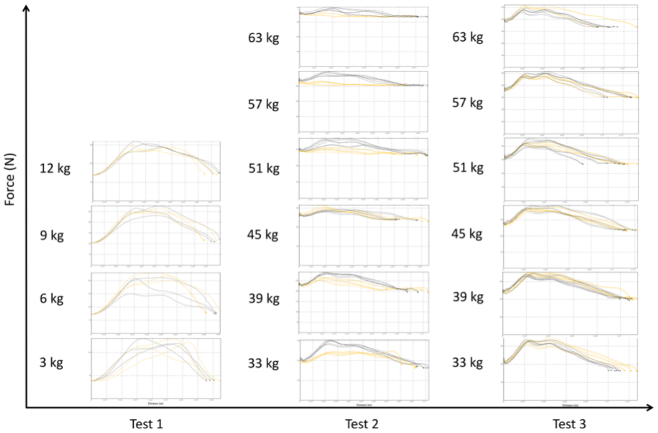

Fig. 4. Isokinetic force (vertical axis) as a function of excursion for unilateral calf raises (yellow=left side; black=right side) for the different loaded tests organized by test session (columns).

Practical Applications

- Robotic resistance can be used to provide different types of resistance (isotonic and isokinetic) and load progressions in the rehabilitation of a calf muscle strain injury (3A)
- Robotic resistance can be used to quantify output (i.e. force and excursion) and thereby used to establish criteria (magnitude and symmetry) in the return-to-play decision making (Step 1 StARRT) (Shrier, 2015).

Limitations

- Generalizations should not be made based on a single case study
- Application of robotic resistance in larger cohorts of athletes with calf muscle strain injuries from different sports of different age, sex and performance level should be explored.

Conflict of interest. Ola Eriksrud is shareholder in 1080 Motion AB.

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