Eccentric loading for Achilles tendinopathy — strengthening or stretching?

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ABSTRACT

The prescription of eccentric loading is considered as a mainstay of non-operative rehabilitation programmes for mid-substance chronic Achilles tendinopathy. Such exercises have some degree of clinical utility in comparison with concentric training and are often referred to as a strengthening programme. Yet the dose parameters of the eccentric loading do not reflect an optimal strengthening programme and specifically avoid the normal eccentric–concentric coupling typical of the stretch shortening cycle. This manuscript identifies the arguments and counterarguments for why eccentric loading rehabilitation is not an optimal strengthening programme. It is proposed that such exercises reflect a specific stretching programme directed at the passive structures. This has two important clinical implications. Firstly, this reinterpretation of the role of eccentric exercises may direct future research into the underlying mechanisms of tendinopathy and, secondly, it may reinforce the importance of adjunct sports specific strengthening programmes.

In recent years the management of chronic Achilles tendinopathy (AT) has moved from addressing inflammatory responses (Achilles tendinitis) to exercise rehabilitation combined with pharmacological interventions.1–4 The non-operative clinical rehabilitation programmes for chronic AT are predominantly focused on progressive eccentric loading.1–5 Various studies have examined the impact of eccentric loading in comparison with other modalities including concentric exercises, splinting and stretching. A systematic review of the role of eccentric loading on AT shows it has some promise for the changes in pain.2 Direct comparison of eccentric and concentric programmes6 suggests that eccentric exercises are more likely to generate a positive outcome (mean VAS change 18 mm, CI −3.7 to 39.7) in pain reduction than concentric exercises. Another recent systematic review shows that rehabilitation with eccentric exercises results in a greater relative rate of return to sport at 12 weeks (relative risk (RR) 2.38, CI 1.56 to 4.18) when compared with individuals who performed concentric exercises.4 Although it is acknowledged that further well controlled clinical trials are required,2,4 these results have influenced clinical rehabilitation practice, with the prescription of eccentric loading for chronic AT being a mainstay of specific exercise therapy. Furthermore, certain prognostic factors are starting to be considered in the efficacy of the eccentric loading profiles with evidence that insertional pain and individuals who are more sedentary may not respond well to the standard eccentric loading protocol. That stated, there have been limited investigations of the training paradigm, i.e. frequency, dose and painful limits, with the majority of research reporting the specific exercise programme that follows the early work by Alfredson et al and Mafi et al.8 Representative programme parameters reported in comparative studies7–9 are shown in table 1.

One key feature of the literature associated with eccentric loading is the reference to the eccentric programme as a progressive strength training programme. At face value, the benefits of the eccentric loading over the concentric resistance training may be explained by well known resistance training principles. These principles suggest that the eccentric actions are more specific, provide greater load via the force–velocity curve and generally provide a more effective resistance training programme. The eccentric loading profile described in the Achilles tendon literature, however, is not optimal for the production of muscle hypertrophy or contractile strength. Clearly, the eccentric-only programme is not specific to the stretch shortening cycle (SSC) nor is it maximally loading the tendon through the functional range (see table 2).

More than just strengthening?

Many rehabilitation therapists would argue that muscle performance deficits are seen in lower limbs with AT when compared with normal matched controls,10 and increases in strength and endurance are observed following eccentric-only programmes. Yet, when eccentric exercises are compared with concentric exercises, the clinical improvements in symptoms and levels of function are clinically more evident than group differences in muscle performance.5 Therefore, it is plausible that the eccentric exercises have underlying mechanisms other than improvement in muscle performance. To further support this, table 3 provides the arguments that the eccentric programme used widely in the rehabilitation of the AT is far from an optimal muscle strengthening programme.

Passive structure stretching programme? (Does the tendon know what the muscle fibre is doing?)

When an external moment is applied to the joint, muscle fibres can create tension to resist the lengthening. This resisting force is transmitted through the tendon irrespective of the muscle fibres shortening (concentric) or lengthening (eccentric). Therefore one may ask “What is the mechanism that makes eccentric loading clinically
effective compared with concentric muscle actions?" or, more simply, “How does the tendon (mid-substance Achilles) know what is happening to the muscle fibre?” This suggests that the eccentric load provides a different form of loading in the tendon and/or that there is communication between the muscle and the mid-substance tendon cells.

Recent research examining the different mechanical responses between eccentric and concentric loading may provide a mechanical basis that could explain either hypothesis. For example, Rees et al11 demonstrated that the peak tendon forces generated by the eccentric and concentric heel lowering and raising do not differ significantly. However, it was noted that during eccentric loading there was a greater degree of force oscillations within the tendon for the eccentric loading. It was proposed that this difference in the mechanical loading profile between the different muscle actions could explain, in part, the clinical efficacy.11

Potentially, the clinical efficacy could be a result of the interaction between the loading profile of the eccentric oscillating action and the range at which the tendon is loaded. With the loading occurring at relatively extreme dorsiflexion it is possible that the forces are predominantly absorbed by the passive structures as opposed to the muscle fibres. This is due to the fact that the muscle fibres are at a less than optimal length in the descending arm of the length–tension relationship. It may be this extreme range in combination with the loading that stimulates receptors in the aponeurosis to stimulate mechanical transduction along the length of the tendon.12 13

Furthermore, the stretching of the tendon at the extreme range of motion may apply a different loading profile across different aspects of the tendon.14 It may be only during eccentric loading at the extreme ranges of motion that the specific source of the pathology is targeted. This may partly explain why tendinopathies with insertional pain may respond poorly to the “standard eccentric loading programme”12 13 and some suggest only lowering to ankle neutral in these specific cases.16

Perhaps it is the unique combination of ankle biomechanics and tendon load profile that explains the clinical efficacy of the eccentric loading. If both of these factors are important, one may question whether the generic “eccentric” programmes can be generalised to other tendons in other parts of the body. The evidence suggests that the eccentric loading profiles are clinically more efficacious at the ankle joint than at other joints, and therefore further understanding of the mechanisms is required to validate that eccentric exercise per se has a direct impact on all tendinopathies.

### Table 1 The eccentric loading programme parameters commonly used for the management of Achilles tendinopathy

<table>
<thead>
<tr>
<th>Exercise parameter</th>
<th>Programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetitions</td>
<td>15</td>
</tr>
<tr>
<td>Sets</td>
<td>Three of two similar exercises (see a and b below)</td>
</tr>
<tr>
<td>Exercises</td>
<td>Eccentric loading only, “good leg up bad leg down”</td>
</tr>
<tr>
<td>a) knee straight</td>
<td></td>
</tr>
<tr>
<td>b) knee bent</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>Twice daily, 7 days per week</td>
</tr>
<tr>
<td>Duration</td>
<td>10–12 weeks</td>
</tr>
<tr>
<td>Intensity</td>
<td>Control parameter — discomfort/pain. Load to discomfort (especially first 2 weeks). Increase load by external loading (Ice and stretch)</td>
</tr>
<tr>
<td>Post-exercise advice</td>
<td></td>
</tr>
</tbody>
</table>

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### Table 2 Reasons and counterarguments for the superiority of eccentric exercises over concentric exercises for musculo-tendinous unit hypertrophy and strengthening in Achilles tendinopathy

<table>
<thead>
<tr>
<th>Argument for</th>
<th>Counterargument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specificity</td>
<td>The Achilles tendon is fundamental to lower limb function. The potential of eccentric loading is maximised in the concentric phase of the SSC and optimises the SSC through strengthening the Achilles tendon.</td>
</tr>
<tr>
<td>Force–velocity advantages</td>
<td>Eccentric actions generate a greater load on the musculo-tendinous unit than concentric actions at the same level of drive. There is no clear evidence that the eccentric loading is any greater during the lowering phase than an equivalent concentric action. The exercises have patients lower themselves from a plantar flexed position. To achieve a lowering the athlete must reduce the plantar flexion substantially. Any increase in level of drive to the plantar flexors would actually slow the heel drop substantially and is the prime method of changing the velocity of the heel drop action.</td>
</tr>
</tbody>
</table>

### MECHANISMS

If the premise that eccentric loading of the triceps surae is clearly not an optimal strengthening programme and it is acknowledged that it has some unique form of stretching stimulus, the question can be raised “What are the possible underlying mechanisms associated with changes seen in pathological Achilles tendons?” Some of the possible factors that may complement any strength or visco-elastic changes may include but are not limited to:

#### 1. Improved homogeneity of the passive structures

It is possible that the pathology within the tendon reflects a heterogeneity in the visco-elastic properties of the tendon. The eccentric load may have a selective impact on how the tendon is loaded during the stretch. This is consistent with the so-called “eccentric” training hypothesis of tendon pathology.17 18 The extreme range (dorsiflexion) and possibly the velocity or oscillations of the loading may also influence the heterogeneity of the tendon substance by providing a differential loading profile to different parts of the tendon.19 Furthermore, it may influence the connective aponeurosis, which could influence a larger element of the whole musculo-tendinous unit. This in turn may alter the combination of the mechanical (elastic recoil) and neurological (spinal reflex) feedback loops required for optimal lower limb function.

#### 2. Modulation of the neurological stretch responses

The SSC relies on the synchronisation of both mechanical and neurological systems to optimise the concentric potentiation and overall movement efficiency.19 The pathogenesis or maintenance of AT may be a manifestation of a mismatch of the neurological and mechanical factors. Aggressive eccentric stretching (especially into pain) may cause peripheral and central neurological modulation of thresholds of activation, and synchronisation of motor units associated with short loop and long loop reflex contributions to the optimal SSC.20 21
Furthermore, the eccentric loading may induce a change in the optimal position of the peak force production with the addition of muscle fibre sarcomeres.19 22 23 This could alter the relationship between the optimal functional ranges of the passive (tendon and aponeurosis) and active (muscle fibres) subsystems.

3. Increased shear forces between the tendon and paratendon structures
The eccentric loading profile has been shown to reduce vascularity as a result of the programme when the tendinopathy is associated with neovascularity.24 This is likely to be associated with the stresses generated within the tendon as well as the mechanical shear force stimulus between the tendon and the paratendon. These forces may inhibit, and possibly decrease, vascular infiltration into the tendon25 and alter the nociceptive paratendon. These forces may inhibit, and possibly decrease, the stresses generated within the tendon as well as the understanding the underlying mechanisms more difficult.

4. Other mechanisms
There are many different aspects that warrant consideration as to why the eccentric loading systems seem to have a clinical advantage in AT. These include elements of pain production and desensitisation that may alter the reflex drive to the lower limb muscles. Another aspect gaining interest is the role of eccentric loading and the adaptation of mechanotransduction signalling in the passive tendon structures26 27 and the proximal aponeurosis or muscle fibres. The fact that there are few well controlled trials associated with the actual dose of the intervention makes understanding the underlying mechanisms more difficult.

CLINICAL SIGNIFICANCE
One aspect that comes from this commentary is that the eccentric-only exercises that dominate the rehabilitation programmes for AT are not primarily a resistance training programme to increase muscle strength. Although we propose that the exercises could be more appropriately defined as a stretching programme, the main clinical message is that, in conjunction with this “stretching programme”, well planned resistance training and a sports specific rehabilitation programme need to be considered.28 Sport-specific functional strengthening and endurance programmes should be used in parallel with the eccentric heel drop programme. Individuals who are not athletes, who have been shown to have poorer response rates, may benefit from a parallel programme of aerobic and lower limb resistance training. Few studies have examined the degree of compliance and other tendon-loading activities during activity of daily living in experimental paradigms. This does not mean that they are not important factors in clinical outcomes.

SUMMARY
The clinical utility of eccentric heel drops for chronic AT is not necessarily in response to an increase in strength of the plantar flexors, since this type of resistance training programme is less than optimal to achieve increases in strength. The reason why these exercises, when compared with other strengthening programmes, have greater clinical utility is unclear. There are possibilities that this type of loading profile has an additional impact specifically on the tendon Achilles due to its being an aggressive stretching programme suited to loading the passive structures. The clinical implication is that specific functional strengthening and endurance programmes should also be used in parallel to the eccentric programme.29

Specific reconditioning exercises that mimic the SSC and return to sport are also suggested to be critical in the efficacy of the stretching programme. These considerations should be part of an effort to investigate optimal combinations of stretching and specific strengthening programmes. Attempts to identify the importance of both strengthening and stretching elements in a rehabilitation programme may provide some insight into the underlying mechanism associated with AT and tendinopathies in general.

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