Development of a home-based exercise intervention for individuals with Achilles Tendinopathy

Problem: Chronic tendon pain (tendinopathy) is a common cause of disability for Canadians which can drastically limit engagement with daily activities while also being difficult to treat[1–3]. Achilles tendinopathy (AT) is typically treated with an eccentric loading exercise regimen (e.g., heel drops)[4,5]; however, long-term adherence to such programs is low and may contribute to slow recovery times and poor prognosis for individuals with AT[6,7]. Development of new and innovative technologies may allow for more precise monitoring of exercise progress, improved patient engagement, and potentially better rehabilitation outcomes.

Background: ***Achilles tendinopathy.*** AT is a repetitive strain injury which commonly presents as painful swelling in and around the Achilles tendon[8,9], with approximately 1.9 million Canadians experiencing Achilles tendon pain in their lifetime[10]. Although the Achilles tendon is one of the strongest tendons in the body, it also suffers from one of the highest injury rates in both athletic and non-athletic populations due to the large forces it sees during locomotion[11] and relatively low safety factor[12,13].

Current treatment modalities. While the physiological influence of exercise on musculoskeletal tissues like bone and muscle is supported within a wealth of studies[14–18], the effects of exercise on tendon function is still in its infancy[19]. That said, tendinopathies are known to reduce tendon stiffness[20,21], and therapeutic strategies targeting increasing tendon stiffness may alleviate functional deficits. In fact, physical therapy interventions involving eccentric and isometric exercises have been shown to induce positive tendon adaptations, functional recovery, and symptom alleviation[11,22–24]. Even though targeted exercise has been shown to improve recovery, optimal loading for AT has yet to be determined and current research suggests that long-term adherence to physical therapy interventions is low[24–26].

Novel exercise intervention. A recent systematic review and meta-analysis of training programs on healthy tendons suggests that programs using heavy loads (at least 70% of maximum voluntary contraction (MVC)) routinely elicit increases in tendon stiffness, regardless of the mode of exercise (concentric, eccentric, or isometric)[19]. Although delivery of exercise programs incorporating these suggestions is feasible in the lab[11], replicating such a program at home is challenging due to low adherence rates[24–26] and poor fidelity to AT rehabilitation programs[27]. Health technologies provide a possible avenue to improve adherence and fidelity to prescribed exercise interventions by incorporating real-time biofeedback, a technique shown to improve engagement and adherence to physical therapy programs[28–31].

Objective: The aim of my PhD is to develop a home-based, high-load, isometric exercise program and associated monitoring technologies to induce positive Achilles tendon adaptation in individuals with AT. Integration of such technologies within a home-based intervention may promote self-managing of health behaviours and engagement within AT rehabilitation while also providing advantages to clinicians who can remotely monitor participant engagement, modify goals, and provide feedback to reduce risk of re-injury[32].

Methods: **Study 1**: *Scoping Review.* To allow for more targeted intervention design towards improving home-based AT treatment, this study will involve a scoping review synthesizing how current exercise-based interventions for AT are being designed and implemented.

Study 2: *Sensor Validation*. Prior to inclusion in the exercise intervention, the accuracy and reliability of two candidate commercial load cells will be independently evaluated in a high-precision mechanical testing device available in the lab (Instron Inc., Norwood, MA). A series of systematically selected loads[33] will be delivered by the mechanical testing device to the load cells. Forces measured by the sensors will be compared to the true loads delivered to assess accuracy and reliability of the candidate load cells.

Study 3: *Intervention Development and In-Lab Evaluation*. This study is split into 2 parts. **Study 3a:** *Stakeholder Needs Assessment*. An online survey will draw on stakeholder experiences with home-based AT rehab and exercise monitoring technologies. Target stakeholders include physical therapy clinicians (n = 3), research staff (n = 2), and a patient partner. Stakeholders will also be asked for any initial requirements or constraints to help guide subsequent development (e.g., users may want 2-way communication with their clinician via the app). Inclusion of key stakeholders in formative development has been shown to improve uptake of research into clinical practice[34,35]. **Study 3b:** *Intervention Development*. Based on an initial intervention design by collaborator Adamantios Arampatzis coupled with outcomes from studies 1 and 3a, a physical prototype will be developed to objectively measure plantarflexor force similar to a seated calf extension. An open source mHealth smartphone app will also be developed to interface with the load cell selected in study 2 via Bluetooth. The app will provide real-time biofeedback to the user in the form of visual/auditory feedback for self-monitoring of exercise performance.

Study 4: *Feasibility Study*. To assess whether the physical prototype and associated app meet the system requirements outlined in study 3a, 10 healthy adults (age 18-65) will demo the exercise program in the lab using the intervention prototype to monitor force and deliver biofeedback in real-time. <u>*Protocol*</u>: The exercise program consists of a predetermined number of sets/reps where the individual executes 70% MVC of isometric plantarflexion while positioned in long-sitting; the program is in alignment with previous work on healthy individuals in our lab[11]. <u>*Outcomes*</u>: Both quantitative (comparison of load monitoring accuracy to same exercise regime conducted on a laboratory-grade dynamometer) and qualitative (survey assessing overall interaction with the novel intervention) outcomes will be assessed. Following this, the intervention will be revised accordingly (e.g., design modifications to improve comfort, fit, app functionality, etc.) then re-evaluated in the pilot study.

Study 5: *Pilot Study*. To test the ecological validity of the exercise intervention protocol prior to testing in a randomized prospective clinical trial, a pilot study will be conducted in 20 healthy individuals (age 18-65) with unilateral AT. <u>*Protocol*</u>: Participants will attend a baseline appointment in the lab in which anthropometric measures will be taken, and they will be introduced to the intervention, app interface, and prescribed exercises. Participants will also perform 70% MVC of isometric plantarflexion of both the affected and unaffected legs in several ankle-knee angle combinations. Gastrocnemius medialis and soleus activity will be measured using surface electromyography. Individuals will then follow a 12-week home-based exercise program using the intervention and associated app; force goals as administered by the app will be modified weekly through the app by study administrators in consultation with research clinicians. <u>*Primary Outcomes*</u>: Applied vs prescribed loading will be assessed (i.e., percentage of prescribed exercise variables – mean load (kg), mean time under tension (s), and their combination (kg•s)). Exercise adherence, fidelity, and patient's perceived barriers/facilitators to engaging in the intervention will be obtained to make any intervention design changes prior to a full-scale RCT. *Secondary Outcomes*: EMG activity will be assessed to demonstrate the effect of ankle- and knee-joint positions on gastrocnemius medialis and soleus activity bilaterally in individuals with AT.

Significance: The proposed work seeks to iteratively develop and validate a novel intervention for home-based AT treatment which uses health technologies to promote user-engagement and potentially reduce rehabilitation times. Further, this home-based intervention platform may be adapted for other home-based treatment strategies which provides users autonomy with remote clinical supervision thereby decreasing in-clinic time and associated costs.

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