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Reliability of the Achilles tendon tap reflex evoked during stance using a pendulum hammer

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ABSTRACT

The tendon tap reflex (T-reflex) is often evoked in relaxed muscles to assess spinal reflex circuitry. Factors contributing to reflex excitability are modulated to accommodate specific postural demands. Thus, there is a need to be able to assess this reflex in a state where spinal reflex circuitry is engaged in maintaining posture. The aim of this study was to determine whether a pendulum hammer could provide controlled stimuli to the Achilles tendon and evoke reliable muscle responses during normal stance. A second aim was to establish appropriate stimulus parameters for experimental use. Fifteen healthy young adults stood on a forceplate while taps were applied to the Achilles tendon under conditions in which postural sway was constrained (by providing centre of pressure feedback) or unconstrained (no feedback) from an invariant release angle (50°). Twelve participants repeated this testing approximately six months later. Within one experimental session, tap force and T-reflex amplitude were found to be reliable regardless of whether postural sway was constrained (tap force ICC = 0.982; T-reflex ICC = 0.979) or unconstrained (tap force ICC = 0.968; T-reflex ICC = 0.964). T-reflex amplitude was also reliable between experimental sessions (constrained ICC = 0.894; unconstrained ICC = 0.890). When a T-reflex recruitment curve was constructed, optimal mid-range responses were observed using a 50° release angle. These results demonstrate that reliable Achilles T-reflexes can be evoked in standing participants without the need to constrain posture. The pendulum hammer provides a simple method to allow researchers and clinicians to gather information about reflex circuitry in a state where it is involved in postural control.

1. Introduction

The tendon tap reflex (T-reflex) is used to assess spinal reflex circuitry both clinically and experimentally. This is typically assessed in relaxed muscles while participants are seated or prone for ease of elicitation and consistency [1–3]. The excitability of the T-reflex is influenced by peripheral factors including the sensitivity of muscle spindles and the state of the muscle and tendon, as well as central factors including modulatory inputs onto Ia afferents and α-motoneurons. Evidence suggests these peripheral and central factors are modulated to accommodate specific postural demands [4–6]. Thus, it is of interest to assess this reflex during states where the reflex circuitry is involved in maintaining posture.

Limited research has investigated the T-reflex in postural muscles during stance [7–9]. These studies have used linear actuators to apply taps to the Achilles tendon and evoke responses in the triceps surae muscles [7–9]. In order to reduce variability in stimulus intensity, the ankle joint was either immobilized [7,8] or the device was coupled to the lower limb [9]. A simple uniaxial pendulum reflex hammer may be capable of applying reproducible stimuli to the tendon without having to take such precautions. Previous work has shown pendulum hammers are effective in providing controlled stimuli and evoking patellar T-reflexes in seated participants [10–12]. However, it is unknown whether a similar device is capable of eliciting reliable reflex responses in postural muscles when standing, as there are natural fluctuations in body sway and muscle activity. We developed a pendulum hammer capable of applying taps to the Achilles tendon during stance. The first aim of this study was to (i) test whether this device is capable of providing controlled stimuli to the tendon to evoke reliable muscle responses during normal stance and (ii) determine

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if it is necessary to constrain postural sway to improve reliability. A second aim of this study was to assess reflex responses across a range of stimulus intensities to help establish appropriate stimulus parameters (i.e., release angle and associated tap force and velocity) for experimental use.

2. Methods

2.1. Participants

Fifteen healthy young adults (10 females; average age = 23.0 ± 1.7 years; BMI = 22.0 ± 1.4) participated in this study. All participants were free of neurological and musculoskeletal disorders that could influence postural control and reflex excitability. Participants provided written informed consent. All procedures were given ethical clearance by the University of Guelph and Brock University research ethics boards.

2.2. Experimental setup

A custom-built pendulum reflex hammer was used to elicit Achilles T-reflexes during stance (Fig. 1). This device had a freely swinging reflex hammer (mass = 130 g) with one degree of freedom. The height of the hammer could be adjusted from ground level to 18 cm above ground level in order to tap the optimal location on the tendon. The tap velocity could be adjusted by changing the release angle. An electrogoniometer (Biometrics SG110, USA) was affixed to the hammer arm to record angular position. These data were monitored online to ensure the use of appropriate release angles. A dynamic force transducer (Brüel and Kjær 8230, Denmark) with a custom rubberized tip was mounted on the reflex hammer to record tap force.

Surface EMG was recorded from the right tibialis anterior (TA) and soleus (SOL) muscles. EMG signals were amplified, band-pass filtered (10–1000 Hz), and sampled at 2000 Hz (Bortek AMT-8, CA). Participants stood with a self-selected stance width on a forceplate (AMTI OR6-6, USA) and the borders of participants' feet were outlined to ensure consistency across trials. Force transducer data were amplified and sampled at 2000 Hz, and electrogoniometer and forceplate data were sampled at 100 Hz.

2.3. Experimental protocol

Participants completed a 60 s trial of quiet standing. Based on this trial, a mean and standard deviation (SD) of centre of pressure (COP) position in the anteroposterior (AP) and mediolateral (ML) directions were calculated for each participant. This was done to designate ±2SD sway boundaries around mean COP position in the AP and ML directions to delineate the participant-specific boundaries of COP movement for the constrained sway stance condition (see below). Two consecutive blocks of 10 tendon taps were delivered under each of two different stance conditions: constrained and unconstrained sway. For the constrained sway condition, participants were given visual feedback from an oscilloscope to maintain AP-COP within the boundaries and verbal feedback from experimenters to maintain ML-COP within the boundaries. Taps evoked while COP fell outside of either the AP or ML boundaries were noted and repeated. No feedback was given to participants during the unconstrained sway condition. The order of stance conditions was randomized between participants and 60 s of rest was provided between blocks. For both stance conditions, a 50° release angle was used and 5–10 s was given between taps in order to prevent the stimulus from being predictable, allow enough time for balance recovery, and prevent post-activation depression [5].

For 13 participants, a T-reflex recruitment curve was constructed by releasing the reflex hammer at angles between 20 and 90° in 10° increments. The order of release angles was randomized and body sway was maintained within the AP and ML-COP boundaries as described above. Five taps were applied consecutively at each release angle with 5–10 s between each tap.

2.4. Follow-up session

Twelve of the original 15 participants returned to the lab approximately six months later and repeated one block of 10 tendon taps under the same constrained and unconstrained stance conditions. To investigate the relationship between homonymous muscle activation and T-reflex amplitude, 10 taps were also applied while participants adopted a slight forward lean (to increase SOL muscle activity). For each stance condition, a 50° release angle was used.

2.5. Data analysis

Theoretical linear tapping velocity for each release angle was calculated using the formula $V = \sqrt{[2gL(1 - \cos\theta)]}$, where g is gravity, L is radius, and θ is release angle. Theoretical tapping velocities were confirmed using electrogoniometer data from a subset of trials.

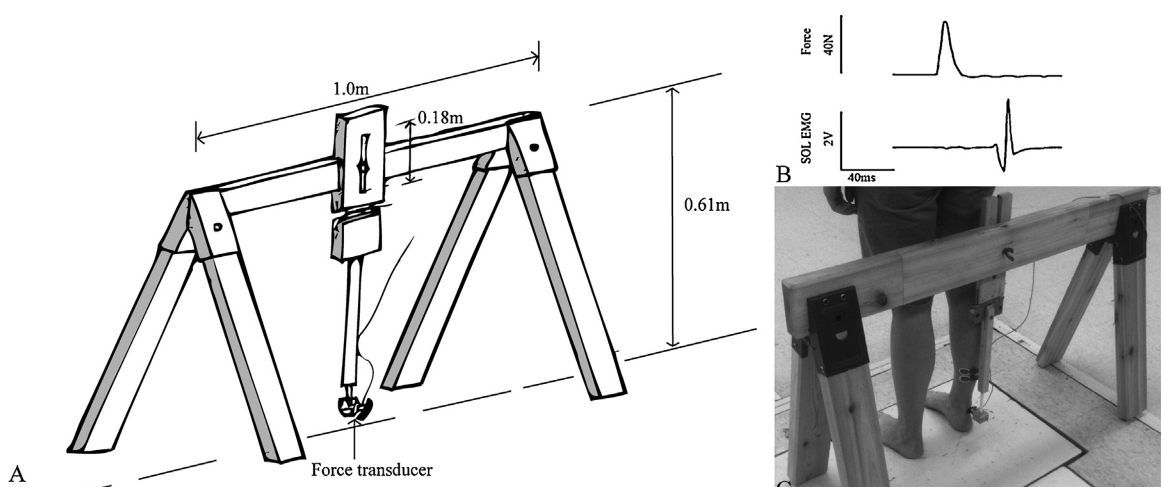

Fig. 1. Illustration of the custom-made pendulum hammer used to elicit the T-reflex during stance (A) and representative force and SOL EMG trace evoked from a 60° release angle (B). Picture of the pendulum hammer aligned to the Achilles tendon (C).