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# Intrarater reliability and agreement of linear encoder derived heel-rise endurance test outcome measures in healthy adults

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ABSTRACT

A linear encoder measuring vertical displacement during the heel-rise endurance test (HRET) enables the assessment of work and maximum height in addition to the traditional repetitions measure. We aimed to compare the test-retest reliability and agreement of these three outcome measures. Thirty-eight healthy participants (20 females, 18 males) performed the HRET on two occasions separated by a minimum of seven days. Reliability was assessed by the intraclass correlation coefficient (ICC) and agreement by a range of measures including the standard error of measurement (SEM), coefficient of variation (CV), and 95% limits of agreement (LoA). Reliability for repetitions (ICC = 0.77 (0.66, 0.85)) was equivalent to work (ICC = 0.84 (95% CI 0.76, 0.89)) and maximum height (ICC = 0.85 (0.77, 0.90)). Agreement for repetitions (SEM = 6.7 (5.8, 7.9); CV = 13.9% (11.9, 16.8%); LoA = −1.9 ± 37.2%) was equivalent to work (SEM = 419 J (361, 499 J); CV = 13.1% (11.2, 15.8%); LoA = 0.1 ± 34.8%) with maximum height superior (SEM = 0.8 cm (0.6, 1.0 cm); CV = 6.6% (5.7, 7.9%); LoA = 1.3 ± 17.1%). Work and maximum height demonstrated acceptable reliability and agreement that was at least equivalent to the traditional repetitions measure.



## 1. Introduction

The heel rise endurance test (HRET) is a popular method of assessing ankle function in research and clinical practice (Hebert-Losier et al., 2009a, 2009b). The HRET involves repetitive concentric-eccentric muscle action of the plantar flexors in unipedal stance until volitional task failure with a side-to-side comparison of the maximum number of repetitions defining the outcome measure (Hebert-Losier et al., 2009a). Maximum repetitions demonstrates acceptable test-retest reliability and agreement (Moller et al., 2005) and is consistently employed as an outcome measure in rehabilitation studies of Achilles tendon rupture (ATR) (Bostick et al., 2010; Buchgraber and Passler, 1997; Moller et al., 2002; Weber et al., 2003).

Silbernagel et al. (2006, 2010) recently introduced a new HRET measuring device in the form of a linear displacement sensor attached to the heel enabling the height of each repetition to be measured and three outcome measures quantified i.e. number of repetitions, total work in joules, and maximum heel rise height in cm. The authors reported that the two novel outcome measures of work and maximum height were more sensitive than repetitions in detecting functional impairment at 6, 12, and 24 months following ATR and recommended their use as outcome measures in future research (Silbernagel et al., 2010; Olsson et al., 2011). Whilst work and maximum height have demonstrated good criterion validity and responsiveness (Silbernagel et al., 2010; Nilsson-Helander et al., 2010; Olsson et al., 2011), the measurement properties of reliability and agreement for these two novel indices have yet to be determined in either healthy or clinical populations. Our purpose was to evaluate these measurement properties, firstly in healthy participants, with a view to employing the HRET as the primary outcome measure in a large multi-centre randomised controlled trial comparing treatment with platelet-rich plasma injection versus placebo in acute Achilles tendon rupture (PATH-2 Trial, ClinicalTrials.gov registration number NCT02302664).

Therefore, the aim of the current study was to measure and compare the intrarater test-retest reliability and measurement agreement of the three HRET outcome measures in healthy adult participants during a standardised and computerised HRET employing a linear displacement sensor. The findings are reported in accordance with recent guidelines for reporting reliability and agreement studies (Kottner et al., 2011).

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## 2. Methods

### 2.1. Participants

Participants were recruited through advertisement posters on University research community notice boards. Inclusion criteria were age 18 years and above, able to give informed consent and follow instructions. Exclusion criteria were history (in either leg) of Achilles tendon pain, previous Achilles tendon rupture, previous major ankle injury or deformity, and recent lower limb injury. Forty healthy participants (20 males & 20 females) volunteered with written informed consent to participate in this study, which was approved by the Institutional ethics committee. Data are presented on 38 participants (18 males & 20 females; mean ± SD age 36 ± 9 years, body mass 71.5 ± 15.3 kg) because two participants withdrew from the study following the first test.

### 2.2. Heel-rise endurance test

To evaluate test-retest reliability and agreement, the HRET was performed on two separate occasions separated by an interval of at least seven days. Since this form of exercise has a large eccentric component and is unaccustomed for most people it often produces the symptoms of exercise-induced muscle damage (e.g. muscle weakness and delayed-onset muscle soreness) and therefore a minimum seven-day recovery period was chosen to allow full recovery between the test and retest (Byrne et al., 2004). To determine the intrarater reliability and agreement of the procedures in our own hands (Weir, 2005), a single trained outcome assessor performed all HRET measurements and was therefore an unblinded assessor. Participants were instructed to maintain their normal levels of physical activity between tests and to avoid any intense physical activity in the hours before testing. Before testing, participants completed the Lower Extremity Functional Scale (scored from 0 to 80 with higher scores indicating better function) (Binkley et al., 1999), had their body mass measured on calibrated class III scales, watched a video demonstration of the HRET, read standardised written instructions detailing their expected conduct during the test, and completed a standardised warm-up. The warm-up consisted of five minutes continuous walking at usual pace followed by 10 double leg heel rises on a 10° incline box guided by a digital metronome at a rate of 30 heel rises·min$^{-1}$.

During the test, participants were instructed to adopt a single leg stance with full knee extension on a 10° incline box facing a wall with only fingertip support; to raise the heel as high as possible on each repetition at a rate of 30 rises·min$^{-1}$ guided by a digital metronome; and to perform as many heel raises as possible (Hebert-Losier et al., 2009a; Silbernagel et al., 2010). The dominant limb was tested first and then the non-dominant limb after three minutes of recovery. The height of each heel-rise was measured by a spring-loaded cord attached to the bare heel of the participant and connected to a linear displacement sensor with a measurement resolution and sample rate of 0.019 mm and 200 Hz, respectively (Encoder, MUSCLELAB™, Ergotest Innovation A.S., Porsgrunn, Norway). Each test was video recorded and a bespoke software integrated encoder and video data (PATH-2, MUSCLELAB™, Ergotest Innovation A.S., Porsgrunn, Norway). Fig. 1 illustrates the experimental set-up. The software was programmed with 1.0 cm concentric (upward) and eccentric (downward) thresholds to provide tolerance for minor movements and signal directional changes (eccentric ≥ 1.0 cm) and new repetitions (concentric ≥ 1.0 cm). Participants either stopped (i.e. volitional task failure) or were audibly instructed to stop with both feet flat on the box whenever any of the following test termination criteria were observed: inability to keep pace with the metronome; inability to maintain full knee extension of the standing leg; or using more than fingertip support. The desired endpoint was volitional task failure, however the outcome assessor used verbal prompts whenever the termination criteria were observed and stopped the test if the participant did not respond to two consecutive prompts.

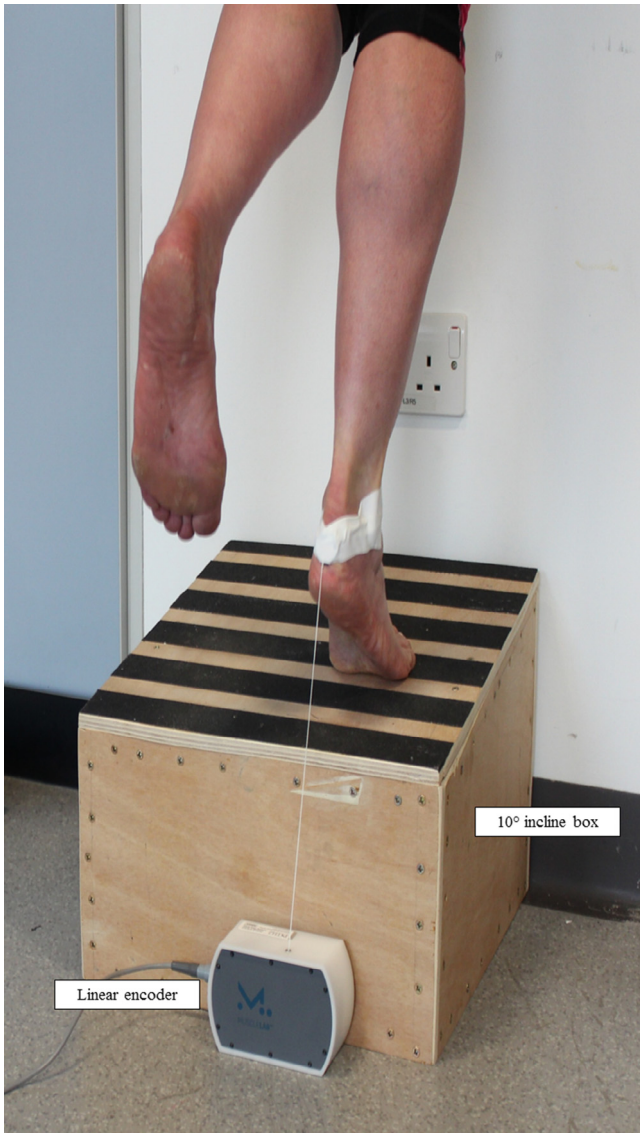


**Fig. 1.** Participant performing the heel-rise endurance test on a 10° incline box, raising the heel as high as possible on each repetition, and with the linear encoder measurement device attached to the heel.

### 2.3. Data processing

Displacement and video data were reviewed after each HRET to identify and eliminate any movement artefacts from the data that occurred after test termination but before the linear encoder had stopped recording data. Large amplitude movement artefacts (mean ± SD height = 29.6 ± 9.0 cm) were observed and removed in 4.6% of tests due to participants moving their leg to alleviate discomfort immediately after test termination. For comparison to previous research, only repetitions with height ≥5.0 cm were included in the analysis (Moller et al., 2005; Svantesson et al., 1998). Repetitions <5.0 cm were observed in 31.6% of tests resulting in a (mean ± SD) minor loss of 1.8 ± 0.9 (range 1–5) repetitions per affected test. These repetitions were removed from individual