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Original Article

Reliability of a device designed to measure ankle mobility

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Study design: Repeated measures design.
Objective: To assess the reliability of a device designed to measure ankle mobility in the clinical setting.
Setting: Spinal Cord Injury Unit, Sydney, Australia.
Methods: Consecutive sample of 15 patients with paraplegia and tetraplegia with injuries of less than 1 year duration was studied. Ankle mobility was measured on two separate occasions 2 or 3 days apart. Stretch torque was standardised and ankle range of motion measured with an inclinometer attached to the footplate. Intraclass correlation coefficients and percent close agreement scores were used to assess agreement between mean measurements obtained on days 1 and 2.
Results: The intraclass correlation coefficient was 0.95 (95% CI, 0.91–0.98). Measurements obtained on day 1 were within 3° of the measurements obtained on day 2 77% of the time and within 6° 97% of the time.
Conclusion: The footplate is a reliable and simple way to measure ankle mobility in people with spinal cord injuries.
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Keywords: joint range of motion; measurement; rehabilitation; ankle

Introduction

Limited ankle mobility, in particular limited ankle dorsiflexion, is a common problem associated with spinal cord injury. Physiotherapists administer different types of interventions in an attempt to maintain or increase passive ankle dorsiflexion.[1–3] It is important that physiotherapists accurately and reliably measure the effect of these interventions. However, treatment effects are likely to be small[3] and will not be accurately detected in the presence of large measurement error.[4]

Typically, clinicians measure ankle mobility by passively dorsiflexing the ankle and using a goniometer to measure the resultant ankle angle.[5] Although this technique is widely used by clinicians, it is prone to error because of the inherent difficulties associated with aligning goniometers and ensuring that the dorsiflexion stretch torque applied by the therapist is constant across different testing days.[5–8] The error associated with measurements of this kind is often greater than any real changes in ankle mobility.[3,4,9] Researchers have overcome this problem by using instrumented footplates. However, instrumented footplates incorporate force transducers, electric motors and potentiometers, and consequently are too expensive and inconvenient for clinical use. Alternate suggestions have been made for measuring ankle mobility. One technique involves applying a constant stretch torque and measuring ankle angle from photographs.[9] While this method of measuring ankle mobility is reliable, it requires two therapists, standardised alignment of a camera and the use of indelible markers. Consequently, it is both time consuming and inconvenient.

The aim of this study was to design and then test a device that could be quickly and easily used by clinicians in their daily practice to measure ankle mobility. The device consists of a footplate attached to a wheel (radius = 0.154 m; see Figure 1). The centre of rotation of the footplate and wheel is aligned and the two rotate together. Weights are hung from the rim of the wheel to ensure that a constant torque is applied regardless of ankle stiffness. An inclinometer positioned on the footplate is then used to measure ankle angle.

Method

In all, 15 consecutive patients undergoing rehabilitation at a Sydney spinal injury unit were included in this study. A further two eligible patients declined to be

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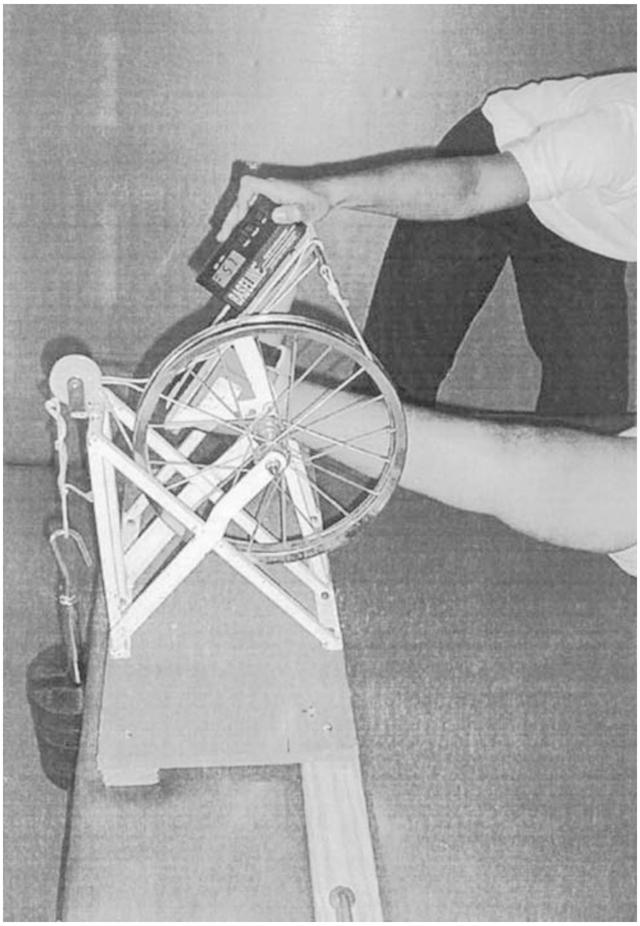

Figure 1 The instrument used to measure ankle mobility. A bicycle wheel is mounted next to a footplate. A rope then extends from the end of the footplate, around the wheel and over a pulley. The weight is hung from the end of the rope. This in turn rotates the footplate. An inclinometer is then used to measure deviation of the base of the footplate from horizontal

involved. Informed consent was attained from all subjects and the authors certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this study. All subjects were currently undergoing rehabilitation and the mean time since injury was 7 months (SD = 3 months). In all, 12 subjects' injuries were classified as ASIA A with no motor function or sensation in the lower limbs and the remaining three subjects' injuries were classified as ASIA C or D with varying amounts of lower limb sensation and motor function.[10] Two subjects had lower motor neuron lesions with no ankle or knee reflexes. All subjects were male, except one, and the mean age was 36 years (SD = 15 years).

Both ankles of all the subjects were tested (30 ankles in total). Repeat measurements were taken 2 or 3 days apart by one of the four therapists. Generally, a different therapist took measurements on days 1 and 2. Therapists measuring on day 2 were not given access to the results of day 1.

Testing on each day followed the same format. Subjects lay supine on a plinth with the knee positioned in extension and the ankle firmly secured in a footplate. A wheel (radius = 0.154 m) was mounted on the side of a footplate with its centre aligned with the centre of rotation of the footplate. The footplate and wheel rotated together. A constant ankle dorsiflexion torque was applied by hanging 11 kg from the rim of the wheel. The wheel acted to ensure that the moment arm (ie, radius of the wheel) of the ankle dorsiflexor torque was constant. In this way, the wheel generated a 17 Nm ankle dorsiflexion torque, regardless of ankle stiffness. The stretch torque was maintained for 3 min prior to each measurement to reduce reflex contraction of muscles around the ankle and knee, and to exhaust 'creep'.

The angle of the footplate in relation to the horizontal position was measured with an inclinometer held on the bottom surface of the footplate. However, footplate angle did not correspond with ankle angle because the tibia was not horizontal. In order to derive ankle angle from footplate angle, the inclination of the tibia was added to footplate measurements. The convention used to report ankle angle was that increases in dorsiflexion accompanied increases in angle.[11]

Following the first measurement, the stretch torque was removed and the whole procedure (including the 3-min prestretch) was repeated. In this way, two measurements were taken of each ankle on each testing day. The mean of the two measurements was used. An intraclass correlation coefficient (ICC 2,1)[12] and percent close agreement of the mean ankle angles attained on the two testing days were then calculated (using SPSS 10.0 for Windows software). Percent close agreement indicates the percentage of pairs of repeat measurements that were within 0, 1, 2, 3, 4 or 5° of each other.

Results

Ankle angle of subjects ranged from 98 to 139° (mean = 125°; SD = 10). The intraclass correlation coefficient, which describes the degree of agreement of the repeated measures taken over the two testing days, was 0.95 (95% CI, 0.91–0.98), indicating high test–retest reliability. The percent close agreement values are detailed in Figure 2. These indicate that measurements obtained on day 1 were within 3° of the measurement obtained on day 2 77% of the time and within 6° 97% of the time.

Discussion

Plantarflexion contractures of the ankle are a common secondary problem of paralysis associated with spinal cord injury. Various therapeutic techniques

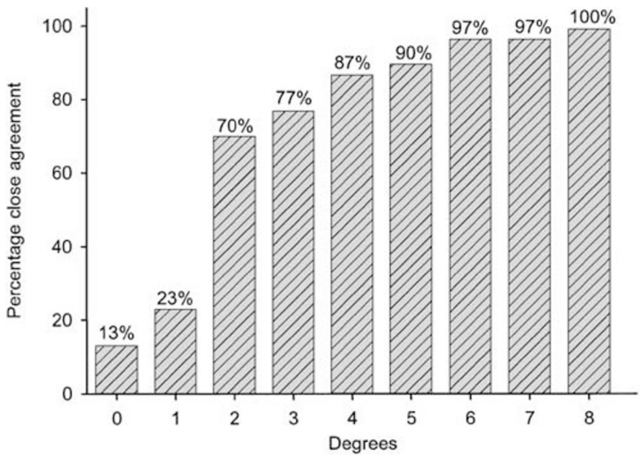

Figure 2 Percent close agreement between measurements taken on day 1 with measurements taken on day 2. These results indicate that measurement taken on day 1 were within 5° of measurements taken on day 2 90% of the time

are used by physiotherapists to maintain or increase passive ankle dorsiflexion.[1–3] In an attempt to quantify the success of these interventions therapists routinely measure ankle mobility. This is typically done by measuring passive ankle range of motion with a goniometer. However, the error associated with this technique is often higher than the expected size of any real treatment effect. Alternate and more reliable methods of measuring ankle mobility have been suggested; however, none are sufficiently simple for widespread clinical use.[1,5–8] The device described in this study was designed for this purpose. It is cheap, easy to make and simple to use. The results indicate that therapists can be 77% confident that a 3° change in ankle angle is real and not because of measurement error.

A source of error when measuring passive ankle angle is variation in the applied torque.[9] Ankle angle is a function of applied torque. The larger the torque, the greater the angle.[3,13,14] The device described in this study uses a wheel attached to a footplate to standardise applied torque. Error is also minimised by eliminating the use of goniometers. Rather, a digital inclinometer held on the bottom flat surface of the footplate is used to measure footplate angle.

The centre of rotation of the footplate is not adjustable and therefore its location does not correspond perfectly with the centre of rotation of subjects' ankle joints. The misalignment of the two centres of rotation is a potential source of error. However, any error introduced by this factor would be consistent across testing days and would not affect reliability. Possibly far greater error would be introduced by attempting to align the centre of rotation of the ankle joint with the device.

A device similar to the one described in this study has been successfully used to construct torque–angle curves of the hip in patients with spinal cord injuries.[15] There is no reason that this device could not also be adapted to measure the mobility of other joints and in other patient groups.

Physiotherapists are aware of the need to objectively measure the success of their interventions. However, often the error associated with measurement procedures is greater than treatment effects. The device described in this study is a simple, cheap and reliable way of measuring ankle mobility. The device could be modified and used to measure the mobility of most joints.

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