Measurements of ankle dorsiflexion in stroke subjects obtained using standardised dorsiflexion force

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This study investigated the reliability of measurements of ankle dorsiflexion obtained using the Lidcombe Template, an instrument that allows the magnitude and direction of force applied to dorsiflex the foot to be measured and standardised. Ten unimpaired physiotherapy students and 21 subjects who had suffered stroke were tested twice. Twenty minutes separated tests. Measurements of passive dorsiflexion range were highly reliable for both groups ($r > 0.92$) when the mean of three measurements was used. Significantly more variability occurred in measurements of impaired subjects than unimpaired subjects. For the subjects tested, for 95 per cent confidence that real differences exist between measurements taken 20 minutes apart, 7 degrees and 3 degrees must be allowed around measurements of impaired and unimpaired subjects respectively. These small error margins confer confidence in the potential utility of this instrument for measuring ankle dorsiflexion.
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Key words: Ankle; Range of Motion; Reproducibility of Results; Research Design

Introduction

The assessment of subjects who have suffered stroke typically includes monitoring changes in dorsiflexion during rehabilitation. The Lidcombe System[(a)] is one method employed by clinicians to measure range of ankle dorsiflexion of subjects following stroke. Despite clinical utilisation, the suitability of these measurements for monitoring changes in range of dorsiflexion in subjects who have suffered stroke remains unidentified. Hence, the present study investigated the reliability and accuracy of measurements when this method was used to measure passive ankle dorsiflexion in subjects undertaking rehabilitation following stroke. The instrument is presented in Figure 1.

To measure passive dorsiflexion using this system, the subject lies supine on a plinth with a standardised roll placed under the knee. The footpiece is placed under the plantar surface of the foot. Dorsiflexion is achieved by applying a specified force to the footpiece via the handpiece. When the predetermined force is attained, a photograph of ankle position is taken. A goniometer is later employed to estimate the angle of dorsiflexion from the photograph.

The instrument evaluated in the present study was designed to standardise the method used to obtain measurements of ankle dorsiflexion. When the ankle is manually dorsiflexed, the amount of force, the location of the force and the direction in which the force is applied could influence the amount of dorsiflexion achieved (Ada and Herbert 1988). The instrument used in the present study includes a force gauge that allows estimation and standardisation of the magnitude and direction of the dorsiflexion force applied. Dorsiflexion angles were estimated from photographs taken at end of range.

The instrument tested in the present study was originally developed for tests of individuals with head injury. Perhaps as a consequence of its theoretical advantages, it is now also employed by therapists involved with the rehabilitation of stroke victims. Estimates of the magnitude of error associated with measurements of dorsiflexion obtained using this system are not available. This information is required by clinicians wanting to determine whether observed measurement differences indicate change in dorsiflexion range, or reflect unpredictable fluctuations in measurements. Given that the device is in use, information about the utility of its measurements would be advantageous.

Reliability of measurements Moseley and Adams (1991) examined repeated measurements of passive ankle dorsiflexion obtained using this instrument. The ICC for inter-rater reliability (five therapists) was 0.97. However, of the 15 subjects tested, five were stroke victims, five had head injuries and five were unimpaired. The small samples of each subject type limit confidence in the sample specific estimates of error. The report did not facilitate prediction of the 95 per cent confidence interval for retest error. No indication of intra-rater reliability was given although, in clinical practice, the same therapist might measure joint range before and after treatment. Of additional importance, the procedure used to measure ankle dorsiflexion was not reported in sufficient detail to allow confident replication. Hence it is unclear whether the measurement instability identified would be similar if a different procedure was used to obtain measurements.

Some time later, Moseley (1993) found the measurements adequately sensitive to reveal changes in dorsiflexion of 10 degrees or more. Nield et al (1993) reported an ICC of 0.97 for repeated measurements of ankle dorsiflexion for 10 unimpaired subjects but provided limited detail of the test procedures employed. A high inter-rater ICC (0.91) was also found for dorsiflexion measurements of five unimpaired subjects tested by Moseley and Adams (1991). Although these high test-retest correlations appear encouraging, clinicians taking repeated measurements of individuals remain uninformed regarding the magnitude of measurement differences required before real differences in dorsiflexion range can be concluded.

If the instrument is used to monitor changes in dorsiflexion during rehabilitation of subjects following stroke, there is the additional consideration that variability in measurements of subjects with stroke may have unique characteristics. It is possible, for example, that the variable muscle adaptation reported to occur in the calf of stroke victims (Meinders et al 1996) might affect the stability of measurements of ankle dorsiflexion. Hence variability estimates obtained from unimpaired subjects, or subjects with different types of impairment, may not be appropriate for interpretation of measurements of subjects who have suffered a stroke.

The number of tests of dorsiflexion range that should be taken when using the instrument is unknown. If unwanted error in measurements is random in direction, averaging a number of measurements might provide more reliable estimates of dorsiflexion than the results of a single test. A single test is, however, more time efficient for the clinician than averaging a series of measurements. In addition, averaging procedures would be appropriate only if repeated measurements did not demonstrate increasing range of movement (ROM) with each test. If this occurred, it would be useful to identify the number of tests required prior to obtaining measurements that are free of systematic increases. The opportunity was taken in this study to evaluate the error reduction associated with averaging procedures and to examine data stability when repeated measurements are taken.

It was not known how much practice with the technique of measuring range of dorsiflexion from the photographs might be required to obtain stable measurements. Of particular interest was whether the person assessing ROM from the photographs changed technique across time, or rapidly standardised measurements of range. Information about this would help determine the training requirements for those estimating dorsiflexion range from photographs.

This study therefore aimed to evaluate:

- The reliability of measurements of passive ROM in ankle dorsiflexion for persons who have suffered stroke when measurements are taken 20 minutes apart. Twenty minutes was selected, as this allowed extrapolation of results to a clinical situation where a 20min intervention might separate assessment and reassessment of range of dorsiflexion.
- Systematic measurement changes associated with repeated testing.
- The magnitude of test-retest error if an average of three measurements are used compared with a singe measurement.
- Measurement errors associated with estimation of range from a photograph.

In preparation for the study, the procedure was tested on a group of young, unimpaired subjects. It was hypothesised that the presence of impairment might result in measurements associated with greater error that those taken of unimpaired subjects. It was recognised that differences between groups might be attributable to either age or impairment. However, if

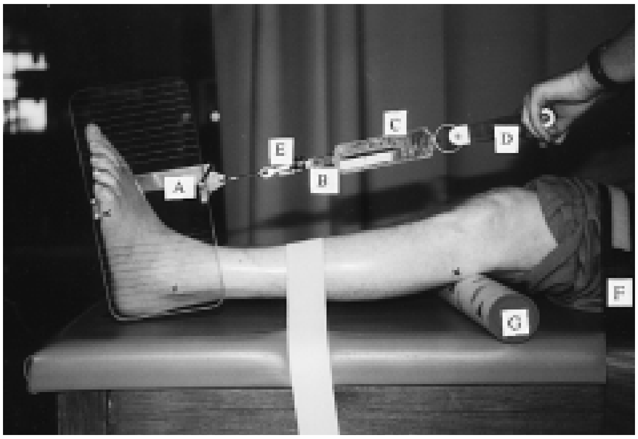

Figure 1. The Lidcombe System.

A: a footpiece attached to a perspex sheet ruled with parallel lines

B: a spring attached to the footpiece

C: a force gauge attached to the spring that indicates the level of force (kilograms) applied to the spring

D: a handpiece attached to the force gauge

E: swivel connecting piece

F: straps around the thigh

G: roll under the knee

A camera mounted on a tripod is used to photograph angle of dorsiflexion.

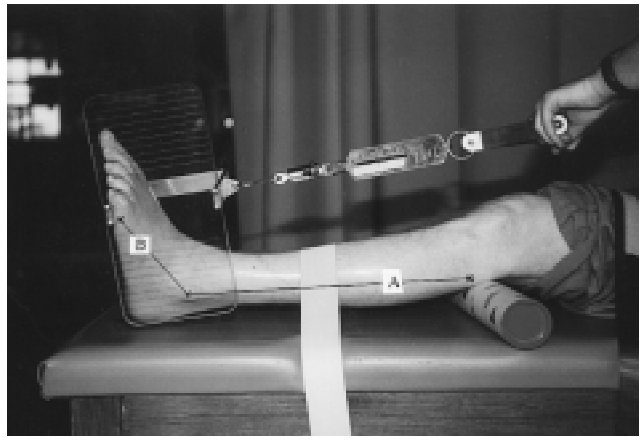

Figure 2. Estimating range of dorsiflexion. On each photograph, two lines are drawn. The first joins the head of fibula to the lateral malleolus (A), the second joins the lateral malleolus to the head of the fifth metatarsal (B). Zero degrees of dorsiflexion is concluded when B is perpendicular to A. As the fifth metatarsal always lay in front of the lateral malleolus, all measurements were positive.

error associated with measurements of hemiplegic subjects was greater, it was hypothesised that the source of the additional error would be the subjects, rather than the assessment procedures, as the same procedures were used to test both groups. Therefore an additional objective became:

- A comparison of the variability in measurements of stroke subjects with that in measurements of young, unimpaired subjects of the pilot study.

Method

Subjects The impaired group consisted of 19 ambulant, and one non-ambulant but weight bearing, stroke patients undergoing therapy at Kingston Centre, Victoria (mean age 75.4 (SD = 8) years). There were four females and 16 males. Constraints on data collection prohibited obtaining equal numbers of male and female participants, but there was no evidence or indication that error in measurements of ankle dorsiflexion should be affected by subject gender. Eleven subjects had suffered hemiplegia affecting the left lower limb, and 10 had an affected right lower limb. All but one had suffered a stroke within three months of being tested. This subject had suffered a stroke eight months earlier. Subjects were asked to participate in the study if they were due to attend therapy on the day of the study and were accepted if they agreed and met the inclusion criteria. Consequently the sample was one of convenience. There were no obvious reasons why measurements of dorsiflexion taken of this sample should have characteristics that were atypical of those that would be obtained from other groups of stroke victims receiving outpatient physiotherapy. Inclusion criteria were that subjects were inpatients ($n = 18$) or recently discharged ($n = 2$), had suffered one stroke affecting the ankle measured and consented to participate. The only exclusion criteria was additional ankle pathology that might influence ankle movement.

In addition, 10 (three male, seven female) unimpaired fourth year physiotherapy students were tested in a pilot study that was conducted to optimise measurement technique prior to testing impaired subjects. Subject mean (SD) age was 24.3 (3.9) years. The study was approved by the La Trobe University Ethics Committee. All subjects gave informed consent.

Equipment The Lidcombe System was used to measure passive dorsiflexion (Figure 1). Measurements were taken with subjects supine on a 63cm high, non-adjustable plinth. A 6.3cm diameter cylinder was placed under the knee of the leg being measured. Photographs were taken using a Pentax P30T camera[(b)] with a Vivitar autothyristor 530FD flash, on an 86cm Daiwa VT 130 tripod. When dorsiflexion was estimated from the photographs, a 12cm clear plastic universal goniometer was used. Statistical analyses were performed using SYSTAT, Version 5.1[(c)].

Procedure Subjects were positioned supine on the plinth with their heels 10 centimetres from the end of the plinth. Heel position was identified using markers on the plinth. Skin markers were placed on the affected lower limb on the head of the fibula, the lateral malleolus and on the head of the fifth metatarsal of the affected lower limb. These points were selected because they were easily identified and were the same areas marked during previous investigations by Ada and Canning (1990) and by Moseley and Adams (1991). Imaginary lines joining these markings allowed alignment of the goniometer arms when estimating dorsiflexion from the photographs.

The camera and flash were placed on the tripod. The centre of the tripod was two metres from the edge of the plinth. The position of the tripod legs and plinth legs were standardised using marks on the floor. During each session in which repeated measurements were taken, once the camera was set up, the tripod was not moved.

To standardise the position of the knee during testing, ankle dorsiflexion was measured with the knee in slight flexion. There were two reasons for this. It appeared comfortable for subjects and also appeared pertinent to measure the effect on dorsiflexion range attributable to soleus in people with stroke, as soleus length has been reported to be more affected by disuse than gastrocnemius (Appell 1990, Goldspink and Williams 1990). Slight knee flexion, approximately 12 degrees, was achieved by placing a cylinder under the subject's affected knee during measurement (Figure 1, G). The cylinder was placed under the knee joint line. It has been proposed that head position may also affect dural tension (Lew and Keating 1995), which could in turn affect range of ankle dorsiflexion. Head position was therefore standardised by the use of the same two pillows for each subject. Two pillows were chosen, rather than one, for subject comfort. Straps were used to stabilise the position of the subject's leg because, in a pilot study, it was found that without a strap around the calf, the subject's heel lifted off the bed and dorsiflexion was difficult to control. Straps were placed approximately 15 centimetres above the knee (Figure 1, F) and around the lower leg.

The location of the force acting to dorsiflex the foot was standardised by the positioning of the footpiece. Force was applied perpendicular to the foot, and this was estimated by visual alignment of the line of pull and the lines on the perspex sheet (Figure 1, A). A swivel joint connected the footplate and the force gauge (Figure 1, E). This enabled the gauge to be turned so that it could be read by the photographer, who had visual advantage over the physiotherapist applying the dorsiflexion force. The photographer signalled when the criterion force was reached. The photographer, with a clear view of the footpiece, also provided directions for aligning the angle of pull with the lines on the perspex sheet. The force gauge remained attached in a standardised position throughout testing

The subject was asked to relax and the instrument was attached (Figure 1). The physiotherapist dorsiflexing the foot stood against the side of the plinth closest to the limb being measured. A slow, passive dorsiflexion stretch was applied by the physiotherapist through the handle until a predetermined force of 14 kilograms was reached. The choice of 14 kilograms was based on the observation that this amount of force achieved end of range dorsiflexion and was comfortable for most people. Two impaired subjects did not tolerate this force, which was subsequently reduced to the maximum they found comfortable (12 kilograms in both cases). For each subject, the same force was applied for each test. Dorsiflexion was performed relatively slowly and maintained for less than 15 seconds.

No previous investigations using this instrument reported the effect on measurements of repeating the test procedure. In the present study, three measurements were taken before and after a 20min rest period. This facilitated direct investigation into the effects on measurements of repeating the test procedure. Hence, after the photograph was taken, the dorsiflexion force was released and the subject rested for 15 seconds. Then, using the same procedure, two additional measurements were taken of the subject, also approximately 15 seconds apart (Repetitions 1-3). The subject then sat in a chair for 20 minutes. Subjects were seated with their feet flat on the floor, approximating plantargrade. The entire process was then repeated (Repetitions 4-6), resulting in a total of six measurements for each subject. Skin markers were not reapplied. The therapist was blind to the joint angles at end of range dorsiflexion as angles were not estimated until photographs were developed.

Photographs were developed and the angles of dorsiflexion were determined (Figure 2). The arms of the goniometer were aligned with the markings on the subject's affected leg. The fixed arm was aligned with the marks on the malleolus and the head of fibula (Figure 2, A). The other, movable arm shared the axis over the malleolus and passed through the mark on the fifth metatarsal (Figure 2, B). Zero degrees of dorsiflexion was concluded when the movable arm was perpendicular to the baseline arm. Since no subjects achieved this amount of dorsiflexion, all measurements were positive. The greater the measurement, the less dorsiflexion a subject had.

Although blind to dorsiflexion angle during the tests, it remained possible that the measurer might remember a previous measurement when estimating angles from photographs. To avoid this, all 186 photographs (six photographs x 31 subjects) were coded, then selected randomly for measuring. One week after the first measurements, the same therapist repeated the estimates of dorsiflexion from the same photographs, again selecting the photograph to be measured at random. A final set of estimates were obtained a week later again. This resulted in 18 measurements for each subject.

Analysis The first stage of the analysis aimed to evaluate the effects on measurements due to group, number of repetitions and experience with measuring from the photographs, and their interactions. An effect due to group would indicate that the unimpaired subjects typically had different ranges of dorsiflexion compared with impaired subjects. An effect due to number of repetitions would indicate that repetitions were changing systematically with repeated testing. This might occur if subjects relaxed with repeated tests and achieved larger dorsiflexion scores on each test. A subject by repetition interaction might occur if, for example, unimpaired subjects demonstrated dorsiflexion ROM that increased with each test, while impaired subjects did the opposite. An effect due to the week on which the photograph was measured would indicate that the person measuring was systematically altering the measurement technique when repeating measurements one or two weeks later. This helped us to evaluate the level of difficulty of the measuring task and to make recommendations regarding training requirements. To evaluate the effect on measurements of ankle dorsiflexion due to type of subject (impaired or unimpaired), when the photographs were measured (Weeks 1-3) and the number of the test repetitions (1-6), a 2 (group) x 3 (weeks) x 6 (repetitions), ANOVA was conducted with repeated measures on the last two factors.

The next stage of analysis aimed to examine the variability in repeated measurements and the effect of averaging procedures. After testing for assumptions underlying the utilisation of linear regression, the means of the first three measurements taken before the 20min rest (Repetitions 1-3) were correlated with the means of the second set of three measurements (Repetitions 4-6) using linear regression. Regressions were performed separately for impaired and unimpaired subjects. The root mean square (RMS) of the residuals around these regressions provided an indication of the average change in measurements across tests.

To provide clinically useful error estimates, the magnitude of the test-retest variability was estimated by subtracting the mean of Repetitions 1-3 from the mean of Repetitions 4-6. The standard deviation of these differences scores was used to calculate the 95 per cent confidence interval for the change required before genuine measurement differences could be concluded. The absolute retest differences for impaired and unimpaired subjects were compared using a two-tailed t-test to determine whether variations in repeated measurements were similar for both groups. Alpha was set at 0.05.

In clinical practice, a therapist working within time constraints might take only one measurement before and after intervention. To examine the variability in measurements when averaging procedures were not employed, the variability in measurements if only one test measurement had been used was also examined. Repetition 1 measurements were compared with Repetition 4 measurements using linear regression and difference scores were again calculated.

To evaluate the magnitude of variability in measurements attributable to repeated estimation of range from the same photographs, Week 1 measurements were compared with Week 2 measurements. For the impaired group, the 126 measurements (21 subjects x 6 photographs) taken on Week 1 were regressed against the 126 measurements made on Week 2. The same was done for the 60 measurements (10 x 6 photographs) taken of the unimpaired group. The means and standard deviations of differences associated with measurements repeated across weeks were also calculated. In addition, a *t*-test comparing the absolute differences in measurements for impaired and unimpaired subjects was used to determine whether the variability in repeated estimations from the photographs was influenced by the presence of impairment.

To confirm the suitability of the intended data analysis strategies, preliminary investigations were conducted. Measurements for each repetition (1-6), and for each week (1-3) averaged across repetitions, were analysed for both groups of subjects. All data were found to be normally distributed when tested using Shapiro-Wilks. Data were also tested for homogeneity of variance using F max and for sphericity using Mauchly's test.

Results

Preliminary data analysis indicated data suitable for comparison using a mixed design analysis of variance. The results are summarised in Table 1.

There were no interaction effects in the 2 (group) x 3 (weeks) x 6 (repetitions) ANOVA. The range of passive dorsiflexion (Figure 3) was significantly smaller for impaired subjects compared with unimpaired subjects ($F_{(1,29)} = 19.6$, $p < 0.001$). No significant effects due to repetition number or week were found (Figure 3). This indicated that the person assessing the angle of dorsiflexion from the photographs did not derive measurements that changed systematically from week to week. Subsequent analyses were therefore conducted using Week 1 measurements.

Assumptions underlying the utilisation of regressions were met. Data correlated were for related pairs of measurements and were normally distributed. Visual observation of the regressions indicated a strong linear relationship between test and retest measurements and measurements appeared homoscedastic.

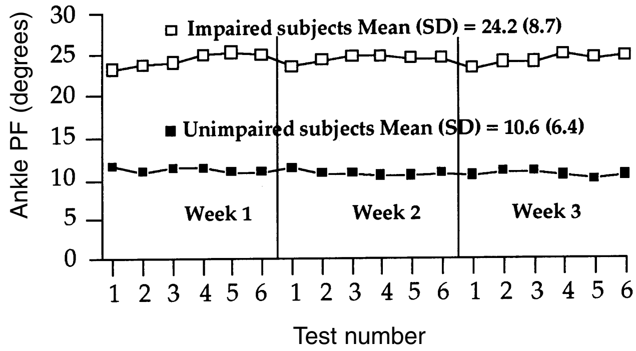

Figure 3. Group means for measurements from Repetitions 1-6 are plotted against the angle of the foot from neutral dorsiflexion/plantarflexion. Greater angles indicate decreased range of dorsiflexion. Measurements appear stable across the six repetitions and similar when the photos are measured each week.

Figure 4 shows the relationship when the average of Week 1 measurements for Repetitions 1-3 was regressed against the average of measurements for Repetitions 4-6. For unimpaired subjects, the product moment correlation coefficient (PMC) was 0.97. For impaired subjects, the PMC was 0.92. The RMS residuals for these regressions were 1.7 degrees for unimpaired subjects and 3.6 degrees for impaired subjects. Because there were negligible systematic changes in retest measurements, these residuals indicate the average differences in measurements taken before and after the 20min rest period.

The absolute differences between the means of Repetitions 1-3 and Repetitions 4-6 for impaired and unimpaired subjects were compared using a two-tailed *t*-test. Retest differences were found to be significantly larger for impaired subjects ($t_{(29)} = 2.1$, $p < 0.05$).

Figure 5 shows Week 1 measurements for impaired subjects (21 (subjects) x 6 (repetitions) = 126 measurements) regressed against Week 2 readings of the same photographs. The PMC was 0.96 and the RMS residuals was 2.6 degrees. The process was repeated for unimpaired subjects (10 (subjects) x 6 (repetitions) = 60 measurements). The PMC for this

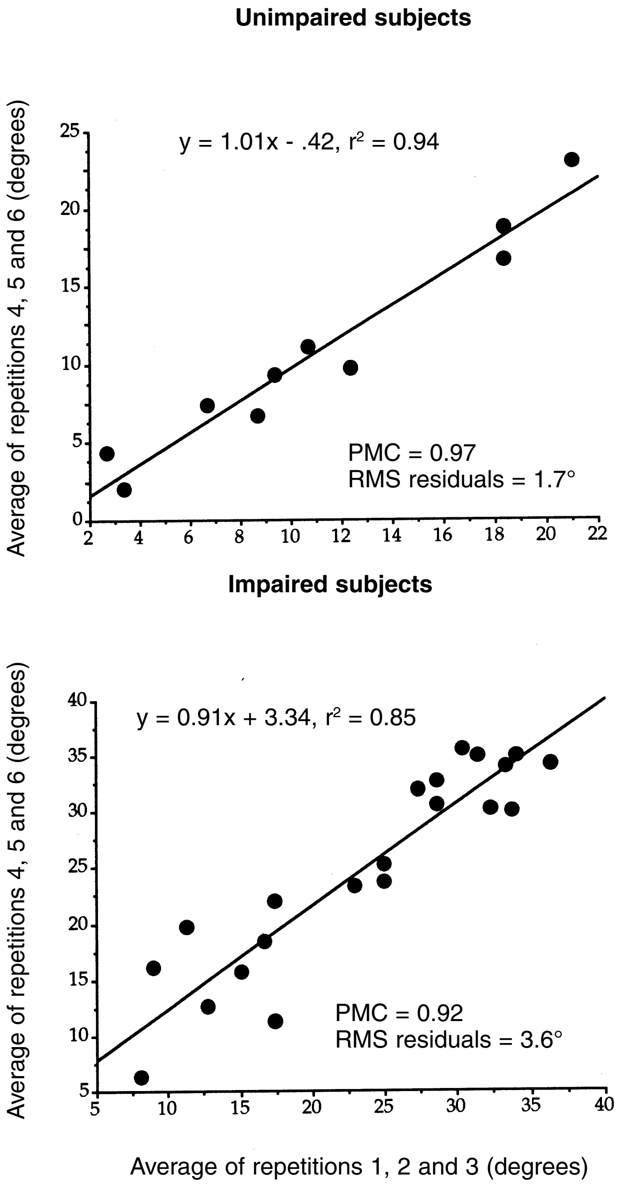

Figure 4. Average of Repetitions 1-3 regressed against the average of Repetitions 4-6. Measurements were those obtained on the first evaluation of photographs (Week 1).

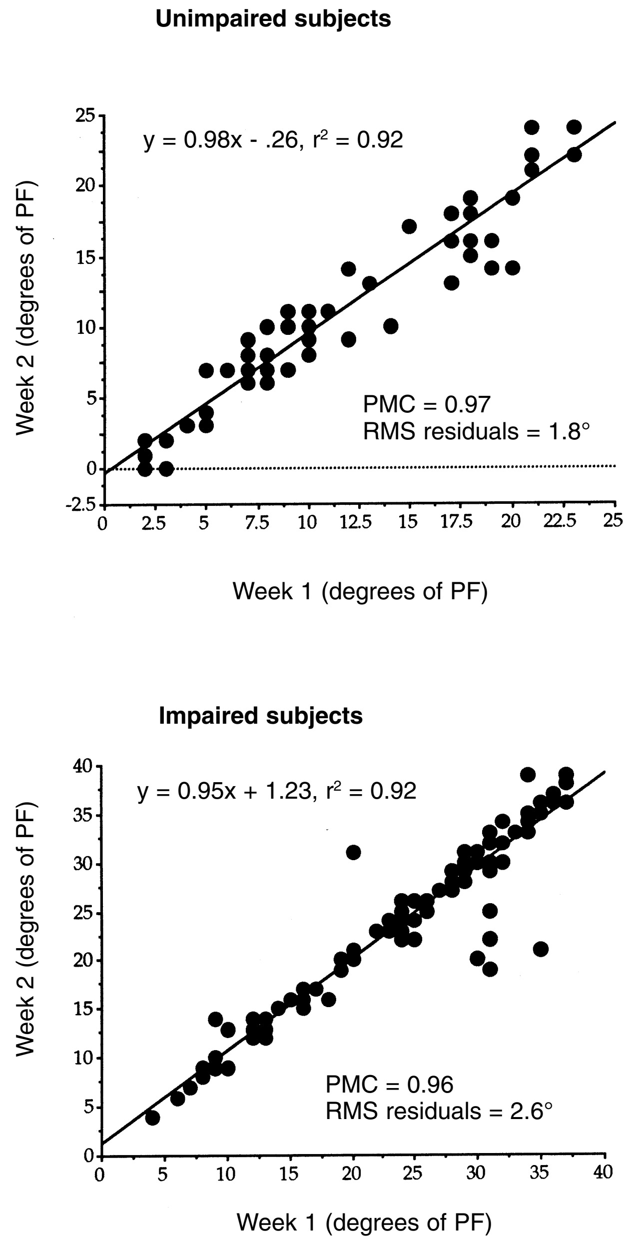

Figure 5. When the photographs were measured twice, variability in repeated estimates of dorsiflexion range was similar for measurements of impaired and unimpaired subjects.

regression was 0.97 and the RMS was 1.8 degrees. A two-tailed *t*-test was conducted on absolute differences for the two groups when Week 1 measurements were subtracted from Week 2. Differences in measurements variability due to interpretation of the photographs did not differ between groups. Hence the additional variability in measurements seen for the impaired subjects was not obviously due to greater error in measuring photographs of impaired subjects.

Variability when no averaging procedures were used was also examined by regressing Repetition 1 against Repetition 4 (Figure 6). For unimpaired subjects, the PMC was 0.95, and the RMS of the residuals was 2.4 degrees (compared with 1.7 degrees for the average of 3 measurements). For impaired subjects, the PMC was 0.92, and the RMS of the residuals was 5.1 degrees (compared with 3.6 degrees under averaging procedures). Predictably, the standard deviation of difference scores was also greater when no averaging procedures were used, 5.3 degrees compared 3.6 degrees for impaired subjects and 2.3 degrees compared with 1.6 degrees for unimpaired subjects. A paired two tailed *t*-test confirmed that measurements were more variable without averaging procedures ($t_{(30)} = 3.96, p < 0.001$).

Discussion

In this study, the range of ankle dorsiflexion was found to be greater for unimpaired subjects tested in the pilot study than for impaired subjects. This may reflect the effect of calf changes that occur as a consequence of stroke (Ada and Canning 1990, Gardiner 1996) and/or changes in dorsiflexion ROM that occur with ageing. Gadjosik et al (1996) found that the range of passive ankle dorsiflexion in older, healthy women was less than that of younger, healthy women.

Of greater interest, the impaired subjects tested in this study demonstrated significantly greater test-retest differences than the unimpaired subjects. The standard deviation of test-retest difference scores was 1.6 degrees for unimpaired subjects and 3.6 degrees for impaired subjects. It is not clear whether the greater variability in repeated measurements was due to age or impairment differences between the two groups, or other unidentified factors. Nevertheless, the consequences of these observations are that error

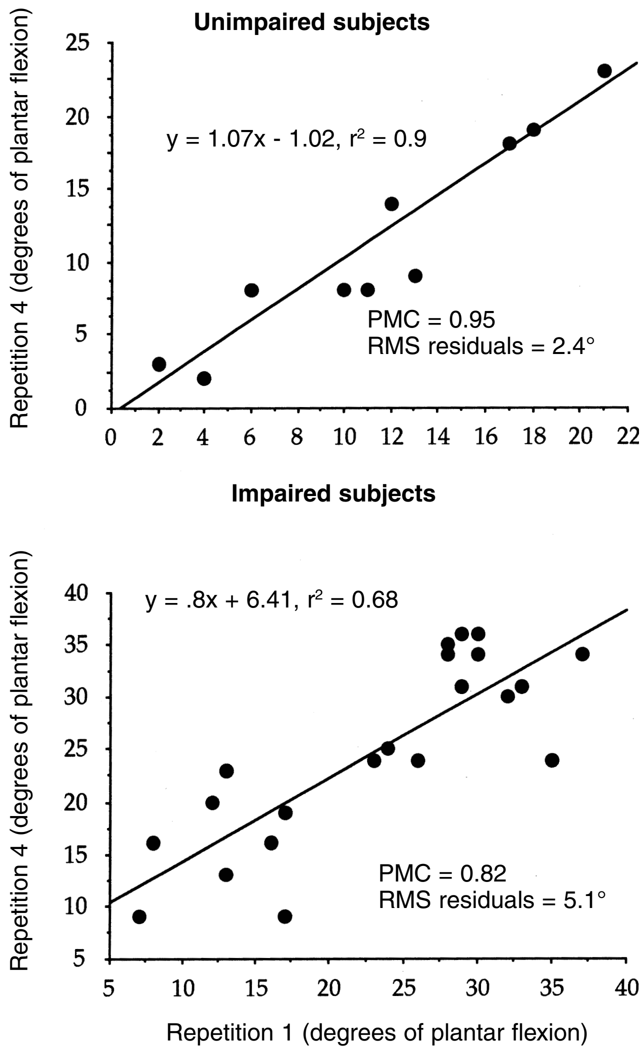

Figure 6. Without averaging of measurements, retest variability increased. The figure shows regressions of Repetition 1 against Repetition 4 taken 20 minutes later.

estimates associated with measurements of ankle dorsiflexion derived from a healthy, young sample are inadequate for describing error associated with measurements of subjects following stroke.

Of additional interest, the error associated with measurements was reduced by the use of averaging procedures. When only the first measurement before and after the 20min rest were considered, the standard deviation of difference scores was 5.3 degrees for impaired subjects (compared with 3.6 degrees when three measurements were averaged) and 2.3 degrees

Table 1 Results of the 2 (group) x 3 (weeks) x 6 (repetitions) ANOVA.

Source	SS	DF	MS	*F*	*p*
Group	22798.65	1	22798.65	19.6	0.000
Error	33731.85	29	1163.17		
Weeks	17.75	2	8.88	1.53	0.224
Error	335.77	58	5.79		
Repetition	17.94	5	3.59	0.19	0.964
Error	2675.61	145	18.45		
Group x Week	9.13	2	4.56	0.79	0.459
Error	335.77	58	5.79		
Group x Repetition	64.58	5	12.95	0.70	0.624
Error	2675.61	145	18.45		
Week x Repetition	11.72	10	1.17	0.63	0.786
Error	537.73	290	1.85		
Group x Week x Repetition	12.43	10	1.24	0.67	0.752
Error	537.73	290	1.85		

for unimpaired subjects (compared with 1.6 degrees using averaged measurements). The reduction in error afforded by averaging procedures was statistically significant.

Bennell et al (1998) published a report on the reliability of measurements of ankle dorsiflexion obtained using lunge. These authors found that the standard error of measurement (SEM = SD x) $\sqrt{}$ $(1 - r)$ where r = the test-retest correlation coefficient) for an average of three measurements of dorsiflexion taken by the same examiner on two occasions was 1.1 degrees. Bennell et al tested young unimpaired subjects, apparently similar to the unimpaired subjects tested in the present study. When the SEM for Week 1 measurements in the present study was calculated, it was also found to be 1.1 degrees. Although the procedures used in these two studies were very different, confidence in, and generalisability of the findings of both studies, is enhanced by the similarity in results.

No effect on measurements due to repetition number was found under ANOVA. In addition, no systematic change in dorsiflexion range with repetition of the test procedure was apparent in the raw data. This suggests that joint or soft tissue stretching on repeated testing did not significantly contribute to variability in range of dorsiflexion. The lack of the subject x repetition interaction effect further suggests that no systematic effect due to repetition number occurred for either type of subject (impaired/unimpaired).

Table 2. Group means for measurements of ankle dorsiflexion. Neutral plantar/dorsiflexion is zero degrees, greater angles representing decreased range of dorsiflexion.

Subject	*n*	Mean (SD)
Unimpaired	10	10.6 (6.4)
Impaired	21	24.2 (8.7)

No significant effects were found associated with when the photographs were read (Weeks 1-3). This indicates that practice with measuring the angle of dorsiflexion did not result in a systematic change in technique that affected measurements. This is particularly encouraging since the person taking the measurements from the photographs in this study was a novice to the technique. In addition, there was no group x week interaction effect, suggesting that no systematic differences in measuring the photographs occurred specific to subject type. There appears to be no advantage, therefore, in taking more than one measurement of a photograph.

The greater variation in retest measurements of the impaired group did not appear to be the result of greater error in estimating dorsiflexion angle with the goniometer for impaired subjects. Similar errors occurred in the measurements taken of the photographs for both groups. Hence the greater variability in measurements of impaired subjects must be due to another cause. The most likely reason for this is greater genuine variability in ankle ROM for stroke subjects.

The results of the present study indicate that when the Lidcombe System is used, to be 95 per cent confident that a change in the range of passive ankle dorsiflexion has occurred, the change must exceed 7 degrees for impaired subjects when an average of three measurements is taken, and 11 degrees when only one measurement is taken. The corresponding values for unimpaired subjects are 3 degrees and 5 degrees (95 per cent confidence interval = 1.96 x standard deviation of difference scores).

Error in the measurement of joint angle can be due to natural variation in available ROM, variation in measurement procedures, and error due to the judgment made by the examiner. Judgment errors and procedural errors are unlikely to contribute more error to measurements than the observed variability in measurements of unimpaired subjects. A difference that could account for the greater error in the impaired sample is the presence of impairment. Another possible explanation might be that older subjects have other characteristics that cause greater variability in repeated measurements than observed in young, unimpaired subjects. However, as stroke victims are typically older, the retest reliability estimated in this study appears appropriate for application to a typical population of stroke subjects. This conclusion would be strengthened if the study were repeated and similar results found for a different sample of subjects with impairment following stroke.

Despite the small errors associated with this test procedure, this method of measuring dorsiflexion range is time consuming and requires several pieces of equipment. It would therefore be of benefit to determine whether similar results could be obtained using a less complicated method. In particular, it appears warranted to identify whether standardising end forces or taking photographs, rather than measuring during the test using goniometry, influence the reliability of the measurements.

Conclusion

This study has demonstrated that the Lidcombe System is a potentially useful device for within-session measurement of passive ankle dorsiflexion in a sample of subjects who have suffered a stroke. It also appears to be a remarkably accurate method for measuring passive ankle dorsiflexion in young, unimpaired subjects. Taking an average of three measurements results in less variable measurements than the use of a single measurement. Using an average of three measurements, for 95 per cent confidence that real change in passive ankle dorsiflexion has occurred, 7 degrees in the stroke population and 3 degrees in a young, unimpaired population should be allowed around an obtained measurement.

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Footnotes [a] At the time of this study, this instrument, designed by Anne Moseley and Roger Adams, was still in template form. Correspondence to Anne Moseley, Rehabilitation Studies Unit, Royal Rehabilitation Centre, PO Box 6, Ryde, New South Wales 1680. [b] Asahi Optical Company Limited, 11-1 Nagata-cho, 1-Chome, Chiyoda-ku, Tokyo 1000. [c] SYSTAT. 1800 Sherman Avenue, Evanston, IL 60201-3793, USA, Statview (Statview SE + Graphics, Version 1.02, Abacus Concepts Inc. 1984 Bonita Ave, Berkeley, CA 94704, USA and SPSS 6.1.1).

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