Movement detection at the ankle following stroke is poor

Mi-Joung Lee, Sharon L Kilbreath and Kathryn M Refshauge

School of Physiotherapy, and Rehabilitation Research Centre, Faculty of Health Sciences, University of Sydney

This study assessed whether sense of movement is impaired at the ankle in persons post-stroke who are able to walk independently. Eleven chronic post-stroke subjects (> 4 months post-stroke) who were ambulatory with or without walking aids and living within the community, and 10 healthy age-matched control subjects volunteered to participate. Proprioceptive acuity at the ankle, measured by sense of movement, was tested at three velocities, 0.1, 0.5, and 2.5 deg/sec, in random order. In addition, ankle range of motion and the distance that subjects walked in 6 minutes were assessed. Stroke subjects were significantly poorer (p < 0.001) at detecting movement at the affected ankle compared with either the unaffected ankle or with the control group at each of the velocities tested. Six out of 11 stroke subjects demonstrated significant impairment in movement detection compared to controls. The usual primary impairments following stroke are loss of strength and loss of co-ordination. However, reduced proprioceptive acuity at the affected ankle may also contribute to a person’s ability to position and load the foot during walking. This could explain the moderate relationship found between proprioceptive acuity and walking endurance in persons following stroke (Spearman’s rho = 0.63 to 0.77). [Lee M-J, Kilbreath SL and Refshauge KM (2004): Movement detection at the ankle following stroke is poor. Australian Journal of Physiotherapy 51: 19–24]

Key Words: Proprioception, Ankle, Sensation, Cerebral Vascular Accident, Physiotherapy

Introduction

Proprioception is comprised of a range of sensations, including sense of movement, sense of position, sense of force and heaviness, and sense of timing of muscular contractions (Gandevia 1996). It is critical to motor control for tasks involving multi-segmental movements, such as walking, and to motor learning. Following stroke, proprioceptive acuity may be impaired (Carey et al 1993, Kim and Choi-Kwon 1996) and may contribute to disabilities in balance and walking (Niam et al 1999, Reding and Potes 1988). However few studies have investigated the effect of stroke on proprioception at the ankle (Lincoln et al 1998, Niam et al 1999), and of those which have examined it, the research design has been flawed (Niam et al 1999), or the measurements have been crude (Lincoln et al 1998). Others have measured proprioception at a joint of the upper limb to infer the status of proprioception elsewhere (Kim and Choi-Kwon 1996, Smith et al 1983). Whilst crude, the study by Lincoln and colleagues (Lincoln et al 1998) suggested that proprioceptive acuity could vary among joints within an individual as a result of a stroke.

The only study to investigate proprioception at the ankle in persons following stroke assessed position sense in subjects who were able to walk with or without an assistive device (Niam et al 1999). Niam et al (1999) reported that subjects with impaired position sense at the ankle demonstrated significantly greater postural sway in both anterior-posterior and medial-lateral directions, a significantly lower Balance Scale score, and poorer stages of leg and foot recovery compared to subjects with intact ankle proprioception. ‘Impaired proprioception’ was arbitrarily defined, and was not based on comparison to subjects’ unaffected ankle nor to the ankle of a control group as these were not tested. Therefore, proprioception status at the ankle after stroke remains unknown.

Thus, the aim of this study was to identify whether proprioception, measured as sense of movement, was impaired in persons following stroke who were able to walk independently. Preliminary data have been presented elsewhere (Lee et al 2002).

Method

Subjects Twenty-one subjects aged between 52 and 86 years were recruited for this study. They included 11 stroke subjects (mean age ± SD: 69 ± 11 years) and 10 healthy, age-matched control subjects (67 ± 10 years). Stroke subjects were able to comprehend and follow simple instructions. They had experienced a stroke, 3 due to haemorrhage and 8 due to infarcts, and 10 neurologically-normal subjects participated in this study. In the group who had experienced a stroke, there were two female and nine male subjects. Three subjects had right-sided hemiplegia and eight had left-sided hemiplegia. Time since the stroke ranged from 10 to 114 months (43 ± 32 months). In the control group, seven subjects were female and three were male. The test ankle of those in the control group was selected randomly, resulting in the left foot being tested in seven subjects and the right foot tested in three subjects. Table 1 presents subjects’ demographic characteristics, including range of motion (ROM) at the ankle, and walking endurance as measured by the 6 minute walk test. The procedures of the study were
explained to subjects and written informed consent was obtained. The study was approved by the Human Research Ethics Committee of the University of Sydney.

**Protocol** Stroke subjects attended the laboratory on two occasions for testing at least one week apart. Each test occasion was approximately 1.5 hrs in duration. The second test occasion was used to determine reliability of the proprioception test procedure. Control subjects were tested on only one occasion. Prior to measurement of proprioceptive acuity, all subjects performed the 6 minute walk test and active range of motion at the ankle was measured with the subject sitting with the knee in relaxed flexion (~70 degrees: same position as the test of position sense) using a universal goniometer. The instructions given to the subjects for the 6 minute walk test were to ‘Cover as much distance as you can, safely, in six minutes. You are allowed to rest if you need to and you may use an assistive device if necessary’. Subjects were informed of the time which had passed after every minute, but were given no other verbal encouragement or feedback. On each occasion, proprioception was assessed at both ankles (the affected and non-affected) in stroke subjects and at one ankle, randomly chosen, in control subjects. For stroke subjects, the order in which the ankles were tested was randomly selected.

Sense of movement in the plantarflexion-dorsiflexion plane was assessed at the ankle using a linear servo-motor under position feedback and driven by a variable ramp generator. The ramp generator was custom designed using LabView™ software and capable of delivering accurate movements of less than 0.001 degree. This setup has been used previously to study sense of movement at the ankle (Clark et al 1985, Refshauge et al 2000). To assess the reliability of the test procedure with stroke subjects, the stroke subjects were retested using the same procedure and assessor, at least one week apart. Intraclass correlations (ICC2,1) were calculated for each movement (dorsiflexion and plantarflexion) at each velocity. According to the terminology proposed by Fleiss (1986), the reliability of testing proprioceptive acuity was ‘high’ (ICC2,1: 0.80 to 0.94) at the medium velocity (0.5 deg/sec) and fast velocity (2.5 deg/sec) for both dorsiflexion and plantarflexion movements. At the slow velocity (0.1 deg/sec), reliability was ‘moderate’ for both plantarflexion (ICC2,1: 0.47) and dorsiflexion (ICC2,1: 0.68) movements.

### Table 1. Characteristics of stroke subjects and healthy controls.

<table>
<thead>
<tr>
<th></th>
<th>Stroke (n = 11)</th>
<th>Control (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years</strong></td>
<td>69 ± 11</td>
<td>67 ± 10</td>
</tr>
<tr>
<td><strong>Time since stroke, months</strong></td>
<td>43 ± 32</td>
<td>–</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male: Female</td>
<td>9:2</td>
<td>3:7</td>
</tr>
<tr>
<td><strong>Affected (tested) side</strong></td>
<td>Right: left</td>
<td>3:8</td>
</tr>
<tr>
<td><strong>6 minute walk, m</strong></td>
<td>324.4 ± 173.1</td>
<td>510.4 ± 107.9</td>
</tr>
<tr>
<td><strong>Active ROM of ankle, degrees</strong></td>
<td>Non-affected</td>
<td>35.9 ± 12.3</td>
</tr>
<tr>
<td></td>
<td>Affected</td>
<td>19.5 ± 17.4</td>
</tr>
</tbody>
</table>

ROM, range of motion. *Values given as means ± standard deviations.

Figure 1. Set-up of the ankle for testing proprioceptive acuity. A servo-motor controlled the velocity and displacement at which the ankle was moved. Subjects wore earmuffs to reduce auditory cues and a screen prevented visual cues of the experimental set-up.
Data analysis

Proprioceptive data from the first test occasion were analysed using analysis of variance (ANOVA) with repeated measures to determine the difference in proprioception between: the affected ankle of stroke subjects and a randomly chosen ankle of control subjects; the affected and non-affected ankle of stroke subjects; and the non-affected ankle of stroke subjects and the randomly chosen ankle of control subjects. The significance level was set at 0.05.

Secondary analysis was performed to explore the relationships between sense of movement at the ankle and the distance covered during the 6 minute walk test, and ROM at the ankle and 6 minute walk distance using Spearman’s product-moment correlation coefficients.

Results

Proprioception at the affected ankle in stroke subjects was significantly poorer than at the unaffected ankle ($p = 0.01$) and at the control ankle ($p < 0.001$) at all test velocities. For example, the number of correct responses out of 10 (mean ± SD) for dorsiflexion at the slow speed for the affected ankle was $0.9 \pm 1.3$, compared with $2.7 \pm 2.5$ for the unaffected ankle, and $5.2 \pm 3.4$ for the control ankle. For dorsiflexion at the fast speed, the number of correct responses out of 10 for the affected ankle was $4.5 \pm 4.2$, compared with $7.8 \pm 3.6$ for the unaffected ankle, and $9.5 \pm 0.9$ for the control group. Proprioceptive acuity at the non-affected ankle of stroke subjects was not significantly different to that of control subjects ($p = 0.11$, Figure 2). Consistent with previous reports (Refshauge et al 2000), proprioceptive acuity decreased with slower velocity ($p < 0.001$).

To determine whether ankle proprioception was affected in all stroke subjects, we compared proprioception performance for the affected ankle of each stroke subject at each velocity to the performance of the control group. Impaired proprioception was defined as a score less than the fifth percentile of the control group. Using this criterion, slow dorsiflexion could not be assessed, as the fifth percentile for the control group was 0/10. However, seven subjects in the stroke group scored 0. For plantarflexion at all velocities tested, and dorsiflexion at the medium and fast velocity, the scores of at least six stroke subjects were less than the fifth percentile (Figure 3), indicating that approximately 60% of our subjects were categorised as having impaired proprioception at the ankle.

The distance that stroke subjects walked in 6 minutes (324.4 ± 173.1 m) was significantly less ($p = 0.01$) than the distance walked by control subjects (510.4 ± 107.9 m). To examine whether proprioceptive acuity was related to walking endurance, data from the stroke and control subjects were pooled. Proprioceptive acuity at the ankle was moderately related to walking distance (Spearman’s rho = 0.63 to 0.77; $p < 0.05$), indicating that subjects with relatively high proprioceptive acuity covered more distance in the 6 minute walk than those with relatively low proprioceptive acuity (Figure 4).

Active ankle ROM of the affected ankle in stroke subjects was significantly reduced (19.5 ± 17.4 deg) compared with the non-affected ankle (35.9 ± 12.3 deg) and the ankle of control subjects (45.8 ± 16.9 deg). Although ROM of the affected ankle was reduced in stroke subjects, it was not significantly related to the distance walked ($p > 0.05$; Spearman’s rho = 0.48).
Discussion

We found evidence that movement sense at the ankle was impaired on the side affected by the stroke, but no evidence of deficient movement sense on the unaffected side. That is, proprioceptive acuity at the unaffected ankle was not significantly different to that of the healthy control group. Using the definition that ankle proprioception was impaired if the score for acuity was less than the fifth percentile of the control group we found that approximately 60% of subjects following stroke had impaired proprioception at the ankle in both dorsiflexion and plantarflexion directions.

This is the first study to test movement detection at the ankle rigorously in persons following stroke. Others have reported decreased proprioception following stroke as a result of testing the upper limb (Corkin et al 1970, Kim and Choi-Kwon 1996, Lincoln et al 1998), or have tested the ankle but have not adopted the suggested requirements of psychophysical test procedures (Coren et al 1966, McNicol 1972, Welford 1976). Niam et al (1999) identified impairment in position sense following stroke, however, in addition to not assessing the unaffected ankle or the ankle of a control group, they provided few details about test procedures, including the number of repetitions used, and the velocity at which the ankle was moved to the test position.

The 6 minute walk test (Guyatt et al 1985) was selected as an
indicator of walking ability for persons following stroke as it is an excellent summary measure of disability related to mobility impairments such as weakness in near-frail or frail older adults (Bean et al 2002, Harada et al 1999, Lord and Menz 2002). It is also a robust measure (Simonsick et al 2000) with little likelihood of having a ceiling effect.

Walking distance was moderately correlated with proprioceptive acuity but not with active ROM at the ankle. Subjects with relatively poor proprioceptive acuity walked a shorter distance in the 6 minute walk test than subjects with relatively high proprioceptive acuity. Of the six subjects who were categorised as ‘impaired’ in plantarflexion detection at the fast velocity, five walked less than 320 m. The subject who received the highest score (5/10) walked the furthest among this cohort. In contrast, the distance walked by the healthy cohort ranged from 382 to 710 m. The relationship between proprioceptive acuity and walking distance is consistent with other pathologies, for example, diabetic neuropathy. Diabetic patients with sensory loss but with no motor loss also have gait impairments, including a slower walking speed, shortened stride length, greater double support time, decreased ankle movement, and decreased vertical and anterior-posterior ground reaction forces when compared to matched controls (Courtemanche et al 1996, Mueller et al 1994).

Within the literature there is some debate as to whether...
somatosensory impairments affect balance and gait (Dettmann et al 1987, Reding and Potes 1988). The moderate correlation of walking distance with proprioception score would suggest that impaired proprioception, although not the primary impairment, does contribute to poor walking. Previous studies (Dettmann et al 1987, Reding and Potes 1988) have not directly assessed proprioception. Reding and Potes (1988) assessed upper limb position sense using a task in which the person was required to 'locate their thumb' blindfolded, and correlated these findings with walking ability. Others, including Dettmann et al (1987), relied on a component of the Fugl-Meyer assessment to correlate with balance and walking. This assessment tool, used clinically, is not a robust measure of sensation.

We hypothesised that proprioceptive acuity at the affected ankle may be affected by limited ROM at the ankle. Shortening of the muscles potentially could affect movement sense as joint angle is estimated from information about muscle length provided by muscle spindle receptors (Burgess et al 1982). Chronic stroke patients often have adaptive shortening of their plantarflexors on their affected side (Thilmann et al 1991), as we found. However, in this group of subjects, proprioceptive acuity was not significantly related to active ROM at the ankle.

Conclusion

In conclusion, following stroke proprioceptive acuity was reduced at the ankle in persons who were able to walk independently. Whilst ankle movement sense was moderately correlated with walking ability, the nature of this association remains to be determined. The next step is to determine whether impaired proprioceptive acuity at the ankle is amenable to training, and whether change in acuity leads to improved walking ability.

Footnote National Instruments, Austin, Texas.

Acknowledgments Mi-Joung Lee is a scholarship holder funded by the National Health and Medical Research Council. Supported by the Faculty of Health Sciences, University of Sydney, Sydney.

Correspondence Dr SL Kilbreath, School of Physiotherapy, University of Sydney, PO Box 170, Lidcombe NSW 1825. Email: <s.kilbreath@fhs.usyd.edu.au>

References


