Loss of proprioception or motor control is not related to functional ankle instability: an observational study

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Questions: Is loss of proprioception or loss of motor control related to functional ankle instability? Are proprioception and motor control related? Is there any difference in proprioception or motor control between ankles with different severity of functional ankle instability? **Design:** Cross-sectional, observational study. **Participants:** Twenty people aged between 18 and 40 years with functional ankle instability associated with a history of ankle sprain more than one month prior. Twenty age-matched controls with no functional ankle instability or history of ankle sprain. **Outcome measures:** Functional ankle instability was classified using the Cumberland Ankle Instability Tool, proprioception at the ankle was measured as movement detection at three velocities, and motor control was measured using the Landing Test and the Hopping Test. **Results:** There was little if any relation between proprioception ($r = -0.14$ to -0.03, 95% CI -0.40 to 0.25) or motor control ($r = -0.08$ to -0.07, 95% CI -0.35 to 0.20) and functional ankle instability. There was also little if any relation between proprioception and motor control except for a low correlation between movement detection at 0.1 deg/s and the Landing Test ($r = 0.35$, 95% CI 0.09 to 0.58). Furthermore, there was no difference between the ankles with or without functional ankle instability in proprioception or motor control. **Conclusion**: By greater than one month after ankle sprain, loss of proprioception does not make a major contribution to functional ankle instability. **[de Noronha M, Refshauge KM, Kilbreath SL, Crosbie J (2007) Loss of proprioception or motor control is not related to functional ankle instability: an observational study. *Australian Journal of Physiotherapy* 53: 193–198]**

Key words: Proprioception, Ankle injuries, Joint instability, Motor skills disorders

Introduction

People who suffer ankle sprains can develop long-term disabling consequences, such as functional ankle instability (Garrick and Requa 1989, Braun 1999). The term functional ankle instability is used to describe symptoms of giving way, weakness, pain, and difficulty in performing functional tasks (Freeman 1965, Hiller et al 2006). The measurement of functional ankle instability up until recently, however, has been a challenge. Although both the Ankle Instability Instrument (Docherty et al 2006) and the Cumberland Ankle Instability Tool (Hiller et al 2006) have been developed to measure functional ankle instability, only the Cumberland Ankle Instability Tool quantifies the severity of instability (Hiller et al 2006).

It has been suggested that functional ankle instability is due to impairments in proprioception, neuromuscular control, postural control, or strength (Hertel 2002). The magnitude of loss of proprioception that is clinically relevant and the relationship between proprioception and function are questions that have been raised but not fully answered (Refshauge 2002). There is some evidence that proprioception and motor control are impaired in people with functional ankle instability (Chambers et al 1982, Lentell et al 1995, Jerosch and Bischof 1996, Refshauge et al 2003). However, these studies recruited participants based on a history of recurrent ankle sprains rather than severity of functional ankle instability and only measured one of the impairments. There has been no attempt to determine the relationship among impairments. Therefore, our research questions were:

1. Is loss of proprioception or loss of motor control related to functional ankle instability?

2. Are proprioception and motor control related?

3. Is there any difference in proprioception or motor control between ankles with different severity of functional ankle instability?

Method

Design

We conducted a cross-sectional observational study to investigate relationships between one measure of proprioception and two measures of motor control in ankles with and without functional ankle instability. The order of measurement was randomised in a way that proprioception for one ankle was combined with one of the motor control measurements for both ankles in each session. The order of testing right or left limb was also randomised. Measurement was completed by one examiner, who was blinded to ankle status. The study was approved by the institution's human ethics committee and written informed consent was gained from all participants before data collection commenced.

Participants

Adults, aged between 18 and 40 years, were recruited through advertisement to form three groups: one group of ankles with instability and two control groups of ankles without instability. The external control group consisted of 20 participants with no history of ankle sprain defined as an inversion injury resulting in pain, swelling, and abnormal gait (Gross 1987) and a Cumberland Ankle Instability Tool

Table 1. Characteristics of participants.

	External control (n = 20)	Instability (n = 20)	Internal control (n = 13)
Age *(yr)*, mean (SD)	30.7 (6.1)	28.3 (6.1)	28.3 (6.1)
Gender *(F:M)*	9/11	16/4	9/4
CAIT *(0 to 30)*, mean (SD)	29.3 (0.9)	17 (4.1)	29.2 (1.0)

CAIT = Cumberland Ankle Instability Tool

score ≥ 28 for both ankles. The instability group consisted of 20 participants with a history of ankle sprain and functional ankle instability indicated by a score ≤ 23 for the affected ankle. The internal control group consisted of the contralateral ankles of the instability group, provided their score was ≥ 28 for that side (13 participants). Exclusion criteria included previous neurological or vestibular impairment or current musculoskeletal injury other than lateral ankle sprain that could interfere with, or contraindicate any of the measurement procedures, or if the acute ankle sprain was of less than one month duration. Characteristics of participants are provided in Table 1.

Outcome measures

Functional ankle instability was measured using the Cumberland Ankle Instability Tool. The tool is a questionnaire with 9 adjectival scale questions (Streiner and Norman 2003) that generates a score between 0 and 30 and has high reliability and discriminative validity (Hiller et al 2006). Scores ≥ 28 indicate stability while scores ≤ 23 indicate functional ankle instability.

Proprioception at the ankle was measured as movement detection at three velocities according to Refshauge et al (2003) and de Jong et al (2005). Participants were seated in a chair with the test foot positioned on the footplate, barefoot. The knee of the same limb was positioned in 90 deg of flexion. Movement was restricted to the ankle by adjusting the participant's position so that when the footplate moved, the movement occurred only about the ankle. To reduce any auditory and visual cues, participants wore earmuffs, and the view of their lower leg was blocked. Participants were regularly instructed to keep their muscles relaxed during measurement.

The ankle was positioned in the middle of its inversion/ eversion range of movement, in approximately 30 deg of plantar flexion. From this initial position, movements into either inversion or eversion were imposed on the ankle by a linear servomotor attached to the footplate. The servomotor (Figure 1) was driven by a variable ramp generator, using a custom-designed program written in LabVIEW[a] software.

Ankle movements into either inversion or eversion were imposed at random time intervals of between 2 and 8 seconds. Participants were instructed to report the direction of any perceived movement as soon as they were able to do so with certainty. Each movement was held for 3 seconds before returning to the initial position to allow time for participants to report the direction. Instructions were repeated throughout measurement to minimise responses in the absence of movement and incorrect reporting of direction (false positive responses). Frequent rests were allowed to enhance concentration.
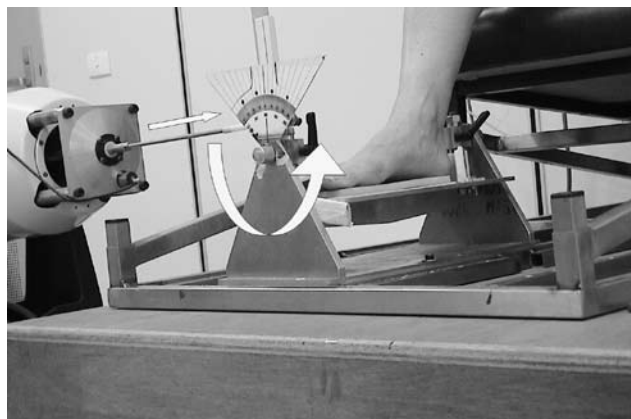
Figure 1. Movement detection apparatus. A linear servomotor generated inversion or eversion movements at the foot. Movements were imposed in sets of 20 (a mix of 10 inversions and 10 eversions) at three different velocities: 0.1 deg/s, 0.5 deg/s and 2.5 deg/s.

The 70 percent detection level was determined for both inversion and eversion movements at each of the three measurement velocities (0.1 deg/s, 0.5 deg/s, and 2.5 deg/s) by using sets of 20 movements of constant amplitude. Each set consisted of a random mix of 10 inversion and 10 eversion movements. After each set, the amplitude of movement was decreased or increased until participants correctly reported 7 out of 10 movements in each direction. The velocities were measured in random order. The starting amplitude was standardised at each velocity: 6 deg at 0.1 deg/s, 4 deg at 0.5 deg/s, and 2 deg at 2.5 deg/s. Because there was no difference in detection level between inversion and eversion movements, the averaged score for inversion and eversion was used in the statistical analysis.

Motor control was measured using the Landing Test (Tropp et al 1984, McGuine et al 2000, Caulfield and Garrett 2004) and the Hopping Test (Jerosch and Bischof 1996). For the Landing Test, we used a force platform to measure three dimensional ground reaction force variability after landing on one leg, principally in the mediolateral direction (Goldie et al 1989). Data from the force platform were sampled at 600 Hz. A reference measure was collected for 10 seconds while participants stood quietly on one leg on the force platform. Participants then stood on one leg on a 16 cm-high step and hopped down onto the force platform, landing on the same foot. Participants were instructed to regain their balance on landing and maintain this posture for 10 seconds. The test was performed barefoot and repeated until 10 successful trials were completed for each leg, with a rest
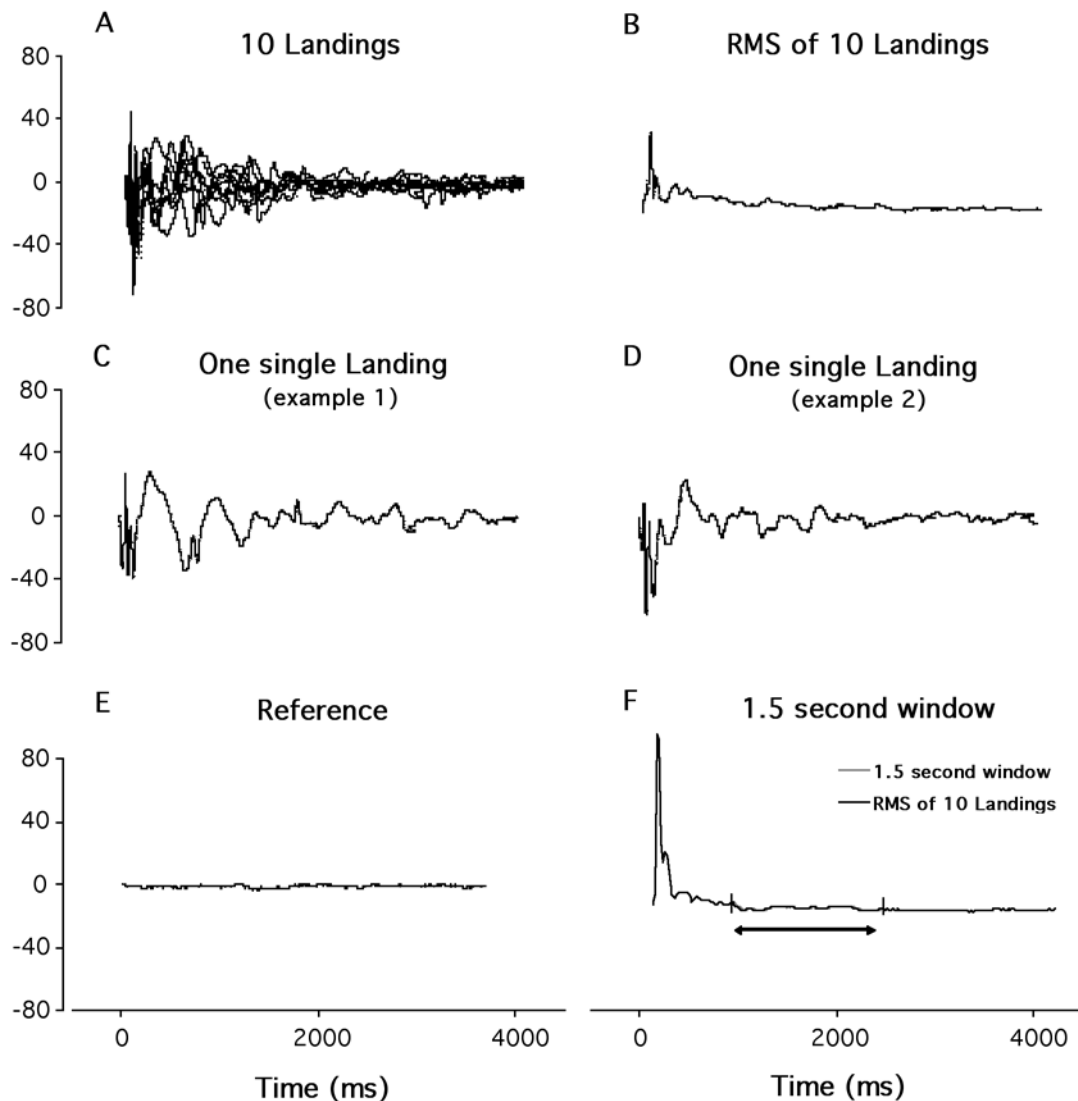
Figure 2. Calculation of the time taken to regain stability after the Landing Test. **A**. Mediolateral force during 10 landings from one participant. **B**. The root mean square (RMS) of the mediolateral force derived from the 10 landings from one participant. **C**. Mediolateral force during one landing from a randomly-selected participant. **D**. Mediolateral force during one landing from another randomly-selected participant. **E**. The variability (SD) of the mediolateral force derived from the reference measure (10 s) was calculated. **F**. RMS of the ten landings and 1.5 s moving window. The variability (SD) of the RMS curve (moving window of 1.5 s duration) was compared to the variability of the reference measure (SD). The point in time immediately preceding the 1.5 s interval during which the variability (SD) in the RMS curve was within 1 SD of the variability of the reference measure was determined as the time taken to regain balance.

of 30 seconds between landings. We determined the time taken after landing to regain balance to the extent displayed during the reference measure (Figure 2).

The Hopping Test was designed to measure single limb motor control on uneven surfaces, and has been shown to differentiate stable from unstable ankles (Jerosch and Bischof 1996). The test involves the time taken to hop barefoot around a course of 4 levelled squares and 4 squares inclined 15 deg in different directions (Jerosch and Bischof 1996) (Figure 3). Participants were instructed to complete the course as fast and as accurately as possible, keeping the foot inside each square. Participants were aware that each time they stepped outside the square or used the other foot, one second would be added to the final time. After six practice trials, the test was performed barefoot and repeated

until five successful trials were completed for each leg, with a rest of one minute between trials. The best of the five trials was used for analysis.

Data analysis

To determine whether loss of proprioception (movement detection) and loss of motor control (Landing Test and Hopping Test) were related to functional ankle instability (Cumberland Ankle Instability Tool scores) we used Pearson's product-moment correlation coefficient (r). Groups were pooled for this analysis. We used the interpretation suggested by Domholdt (2005) as follows: 0 to 0.25 = little if any correlation; 0.26 to 0.49 = low correlation; 0.50 to 0.69 = moderate correlation; 0.70 to 0.89 = high correlation; 0.90 to 1.00 = very high correlation.
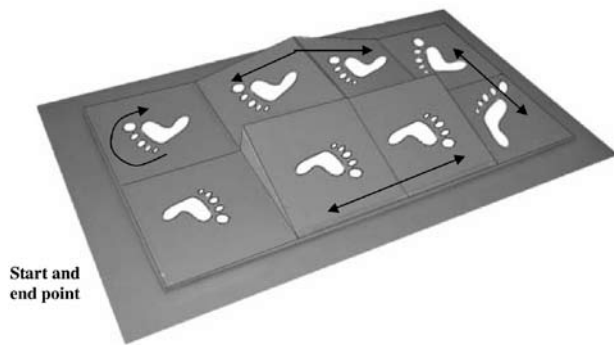
Figure 3. Hopping Test. Participants hopped in each of the 8 squares. They started in one direction, turned, completed the course in the opposite direction, and finished at the same starting point.

Table 2. Relationship between all measures reported as Pearson's *r* (95% CI).

Measure 1	Measure 2	Relation between measures
Movement detection at 0.1 deg/s	CAIT	–0.14 (–0.40 to 0.13)
Movement detection at 0.5 deg/s	CAIT	–0.03 (–0.31 to 0.25)
Movement detection at 2.5 deg/s	CAIT	–0.08 (–0.35 to 0.19)
Hopping Test	CAIT	–0.08 (–0.35 to 0.20)
Landing Test	CAIT	–0.07 (–0.34 to 0.20)
Movement detection at 0.1 deg/s	Hopping Test	–0.10 (–0.37 to 0.17)
Movement detection at 0.5 deg/s	Hopping Test	–0.04 (–0.31 to 0.23)
Movement detection at 2.5 deg/s	Hopping Test	–0.02 (–0.29 to 0.26)
Movement detection at 0.1 deg/s	Landing Test	0.35 (0.09 to 0.58)
Movement detection at 0.5 deg/s	Landing Test	0.26 (–0.01 to 0.50)
Movement detection at 2.5 deg/s	Landing Test	0.17 (–0.10 to 0.43)
Hopping Test	Landing Test	–0.27 (–0.51 to 0)

CAIT = Cumberland Ankle Instability Tool

To determine whether proprioception (movement detection) and motor control (Landing Test and Hopping Test) were related we used Pearson's product-moment correlation coefficient (*r*). Groups were pooled for this analysis. Domholdt's (2005) interpretation was also used for this analysis.

To determine whether there was any difference between groups in proprioception (movement detection), a two-way, repeated-measures analysis of variance (ANOVA) was used. The within-group factor was velocity (0.1 deg/s, 0.5 deg/s, and 2.5 deg/s) and the between-group factor was group (instability, internal control and external control). To determine whether there was any difference between groups in motor control (Hopping Test and the Landing Test), univariate ANOVA was used.

For the external control group, only data from one randomly selected ankle were used in the analysis. Results were considered significant at the $p < 0.05$ level.

Results

Relationship between loss of proprioception and functional ankle instability and between loss of motor control and functional ankle instability

When the groups were pooled, there was little if any relation between proprioception ($r = –0.14$ to $–0.03$, 95% CI $–0.40$ to 0.25) or motor control measured using the Landing Test ($r = –0.07$, 95% CI $–0.34$ to 0.20) or the Hopping Test ($r = –0.08$, 95% CI $–0.35$ to 0.20) and functional ankle instability (Table 2).

Relationship between proprioception and motor control

When the groups were pooled, there was also little if any relation between proprioception and motor control (Table 2) except for a low correlation between movement detection at 0.1 deg/s and the Landing Test ($r = 0.35$, 95% CI 0.09 to 0.58). Furthermore, the Hopping Test bore little if any relation to the Landing Test ($r = –0.27$, 95% CI $–0.51$ to 0).

Difference in proprioception and motor control between groups

There was no difference between the ankles with or without functional ankle instability in proprioception (F = 0.48; $p = 0.62$), or motor control measured using the Landing Test (F = 0.42, $p = 0.66$) and the Hopping Test (F = 0.55, $p = 0.58$) (Table 3).

Discussion

This study was designed to answer three questions. The first was: *Is functional ankle instability related to impaired ankle proprioception or motor control?* We found no relationship between functional ankle instability and loss of proprioception or motor control. The lack of a relationship suggests that impaired proprioception does not explain functional ankle instability. Participants in the current study were allocated to a group based on their performance on the Cumberland Ankle Instability Tool (Hiller et al 2006). Although the measurements used for proprioception and motor control did not challenge participants in exactly the same activities used in the tool, it is clear that there is no generalised deficit in performance.

The second question was: *Are proprioception and motor control related?* Although the relationship between proprioception and motor control at the ankle has not previously been measured, there are reports implying such a relationship (Freeman et al 1965, Tropp et al 1984, Lentell et al 1995). However, in the present study, we found no strong or even moderate correlation between proprioception and motor control. The lack of a relationship may be the result

Table 3. Mean (SD) for each group and difference (95% CI) between groups for proprioception and motor control.

	Groups			Difference between groups		
	External control n = 20	Internal control n = 13	Instability n = 20	External control minus Instability	Internal control minus Instability	External control minus Internal control
Proprioception						
Movement detection *(deg)*						
0.1 deg/s	5.3 (1.3)	5.4 (1.2)	5.8 (0.8)	−0.5 (−1.17 to 0.17)	−0.4 (−1.08 to 0.28)	−0.1 (−0.98 to 0.78)
0.5 deg/s	4.4 (1.5)	3.9 (1.0)	4.6 (1.0)	−0.2 (−0.99 to 0.59)	−0.7 (−1.4 to 0)	0.5 (−0.43 to 1.43)
2.5 deg/s	2.0 (1.2)	2.1 (0.7)	2.3 (0.9)	−0.3 (−0.96 to 0.36)	−0.2 (−0.78 to 0.38)	−0.1 (−0.82 to 0.62)
Motor control						
Landing Test *(ms)*	1442 (417)	1537 (422)	1551 (321)	−109 (−340 to 122)	−14 (−268 to 240)	−95 (−388 to 198)
Hopping Test *(s)*	7.9 (1.2)	8.3 (1.3)	8.3 (1.5)	−0.4 (−1.26 to 0.46)	0 (−1.03 to 1.03)	−0.4 (−1.3 to 0.5)

of the different requirements of each measurement. Some major differences include the velocity of ankle movement at which the measurement was performed, the passive or active nature of the measurement, and whether other sensory systems could contribute to the performance. It seems that the measurements of motor control are challenging different aspects of ankle neurophysiology when compared to our measurement of proprioception because they involve more sources of input (eg, mechanical, visual, muscular inputs). Our findings suggest, therefore, that even when motor control is impaired, loss of proprioception is not the reason for the deficit.

There was only one significant correlation between proprioception and motor control. Movement detection at 0.1 deg/s was significantly, albeit poorly, correlated with the Landing Test. This correlation may be related to the similar velocity of ankle movement at which each measure was performed. It has been demonstrated that quiet standing involves body sway, with movements occurring at the ankle at approximately 0.1 deg/s (Fitzpatrick and McCloskey 1994) and therefore the regaining of balance as required in the Landing Test may have been achieved at ankle movements of approximately 0.1 deg/s. One measure of proprioception required detection of movements at 0.1 deg/s without reliance on other sensory systems. Successful completion of both these measurements required perception of ankle movement at similar velocities and this may form the basis of the relationship. However the results for movement detection at 0.1 deg/s explained only 12 percent of the variance in the Landing Test ($r = 0.35$, Table 2).

Our results raise the question of whether small deficits in proprioception at the ankle are relevant either clinically or for activities of daily living. There seems to be an assumption that poor proprioception after ligament injury will result in poor motor control and function, but such assumptions have not been supported (Friden et al 2001, Ageberg et al 2005, Fonseca et al 2005). In the present study, the lack of correlation between proprioception and motor control

suggests that small impairments in proprioception do not make a major contribution to loss of motor control.

There was no relationship between the two measurements of motor control. This finding is similar to research that found a low correlation between two physiological measurements of proprioception in people with ankle sprain (de Jong et al 2005). These authors concluded that no single measurement of proprioception is adequate to describe the proprioceptive status of a patient after an ankle injury. Similar findings have been reported for other joints (Grob et al 2002, Djupsjobacka and Domkin 2005). It seems reasonable, according to our findings, to extend this conclusion to motor control. Taken together, these findings suggest that both proprioception and motor control should be measured and that they should be measured using various methods.

The third question was: *Is there any difference in proprioception or motor control between groups of ankles from individuals with different levels of functional ankle instability?* In contrast to previous studies, there was no difference between groups in either proprioception or motor control. However, previous studies differentiated participants based on ankle sprain history, with little or no consideration of current functional instability status (Jerosch and Bischof 1996, Refshauge et al 2003). The measure of functional ankle instability used in the current study covered activities that were not exactly the same as those used in the measures of proprioception and motor control. A future challenge is to determine the impairments that underlie the limitations in activities covered in the Cumberland Ankle Instability Tool.

In conclusion, proprioception was not necessarily impaired some time after an ankle sprain and loss of proprioception did not appear to make a major contribution to functional ankle instability. Neither was loss of proprioception related to loss of motor control, which may be due to different characteristics of each outcome measure, such as velocity, physiological systems involved and whether the movement at the ankle was passive or active.

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