Functional instability in non-contact ankle ligament injuries

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Abstract

***Objectives*—To measure objectively functional standing balance in the acute stages of non-contact ankle sprain, and to compare patients with controls.**

***Methods*—A Chattanooga balance machine was used to measure postural stability in patients with acute ankle sprain and uninjured controls over a two week period, in one and two legged stance, with eyes open and closed. Participants also completed the Olerud and Molander questionnaire to provide a subjective measure of ankle function.**

***Results*—There was a highly significant improvement in questionnaire scores for the patients during the study period (p<0.0001). Patients appeared to be less stable than controls in all balance tests, although the difference did not reach significance. There was evidence of improvement over time in the number of tests successfully completed on the injured leg in single legged stance with eyes closed (p = 0.043) between visits 1 and 3.**

***Conclusions*—The patient group showed a subjective improvement, which supports clinical experience of treating acute ankle injuries. There is some evidence that on average the patient group appeared to be less stable than controls in all balance tests, although the difference did not reach statistical significance, even on the uninjured leg. There is a need to carry out further studies to confirm the results found in this pilot study and to investigate the hypotheses generated. It would be useful to evaluate a simple test that could be used clinically to monitor progress after ankle injury, and also to identify athletes with decreased functional stability, who may be more at risk of sustaining ankle injury.**

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Sprain of the lateral ankle ligaments is one of the most common injuries sustained during sport.[1–3] The most common complications following ankle sprain are mechanical and functional instability,[4 5] and it has been suggested that impaired proprioception after ankle injury may be a contributory factor in this instability.[6–10] The functional entity of balance is the result of a complex central integration and analysis of vestibular, visual, touch, auditory, and proprioceptive inputs from the lower limbs and neck.[5 8] Joint position sense at the ankle itself has inputs from both proprioceptors in the joint capsule and from muscle stretch receptors.[5 7 8 11] There is no conclusive evidence for the relative contributions of these proprioceptors, as shown by the use of the local anaesthetic lignocaine to block the afferent input of joint proprioceptors.[12 13] Much of the previous work has looked at passive awareness of joint position, with no assessment of functional balance in the standing position.[6 9 10] Earlier work evaluating functional stability after ankle injury looked at chronic rather than acute cases.[6 7] More recent work suggested that wobble board training for 12 weeks after ankle sprain effectively reduced the number of recurrent sprains, as measured subjectively by questionnaire and interview.[4]

Clinically, it is most important after an ankle sprain for the patient to regain full function and sufficient functional stability to prevent recurrent sprains. We have been concerned with the number of ankle injuries that present for physiotherapy, and the proportion of patients presenting with recurrent sprains, many of whom claimed that they had not received adequate physiotherapy after the initial injury. We were interested in objectively measuring functional standing balance in the acute stages of non-traumatic ankle sprain, evaluating any improvement with therapeutic intervention over the two weeks after injury (11 days of testing), and comparing patient stability with that of a control group. We did not aim to differentiate between the contributions of the individual components of the balance equation, but wished to examine clinical testing of functional balance in a variety of different stances with eyes open and closed.

The principal of functional balance testing is to measure centre of balance (COB) and the limits of postural stability, providing observers with quantitative information about the sensorimotor systems involved in postural control. In this study, a Chattanooga balance machine (Chattanooga Group Ltd, Bicester, Oxfordshire, UK) was used to measure postural stability in patients and controls with acute ankle sprain. It was originally designed to help clinicians quantify disturbances in postural stability and balance in groups of patients with, for example, neurological disturbances.[14]

Methods

SELECTION OF INJURED SUBJECTS AND HEALTHY CONTROLS

Approval was obtained from the Lothian research ethics committee. Patients with acute ankle injury were recruited from patients presenting to the University of Edinburgh Fitness Assessment and Sports Injury Centre (FASIC) over a two year period. Controls were recruited from regular users of the Edinburgh University Sports Centre. Patients had sustained a non-contact grade I or II ankle injury,[15] either new or recurrent on the same side, and presented for assessment by the third day after the injury. Participants were aged between 18 and 25. People older than 25 were excluded as there is evidence that proprioception and balance decline after this age.[16] Other exclusion criteria for both groups were any other lower limb, back, or neck injuries, or any balance or vestibular problems. This was verified by questionnaire and direct questioning. Nineteen patients and 18 controls were recruited and all gave written informed consent. The original intention had been to recruit 20 patients over the duration of a year as a pilot study. This target was not reached in the first year, because of the strict exclusion criteria, and the data collection period was extended for a further year to recruit sufficient numbers for statistical analysis. The exclusion criteria were necessary as these factors all affect balance and could affect the results.

TIMING OF DATA COLLECTION

Patients were seen as part of the study on three occasions. The first time was on day 3 of their injury (with date of injury taken as day 0), and then on days 7 and 14. At each visit, each patient was examined by one of two physiotherapists and treated appropriately from a standardised treatment list, including ice, ultrasound, interferential, strapping, and deep transverse frictional massage. The treatments given were recorded in the patients' medical notes. Each patient was also given instruction on the stretching, strengthening, and proprioceptive retraining they were to carry out each day. After assessment, the patients were then evaluated on the Chattanooga balance machine. To minimise observer differences, all evaluations were performed by the same three operators. Inter-rater variation in recording the data should be minimal because the operators merely had to press the start button on the computer once the subject was in the standardised test position. Controls were also seen on three occasions, at the same time intervals, when they were evaluated on the Chattanooga balance machine. They were asked not to practise the test positions between visits.

METHOD OF DATA COLLECTION

The Chattanooga balance machine measures body weight and distribution over time and allows postural stability to be measured in two or one legged stance, with eyes open or closed, on either a static or dynamic platform.[14] The machine was calibrated and tested for reliability using a series of weights. Postural sway was measured using a static platform with participants standing barefoot on the four footplates. The footplates contain electronic pressure transducers and are adjustable to allow for testing during two and one legged stance. Each test performed evaluates three aspects of postural sway:

(1) COB: average x and y coordinates are plotted using the point between the feet where the ball and heel of each foot is taking 25% of body weight, as a reference point (COB).
(2) Sway index (SI): a function of the time and distance the subject spends away from his or her COB. The greater the SI, the greater the degree of postural sway.
(3) Sway distance: the maximum anterior/posterior and left/right movement in cm away from the subject's COB.

A strict protocol was used for each test. All evaluations were made in the absence of any strapping or external support, which may provide extra stability to the ankle joint. Participants were tested in the following order: two legged stance with eyes open, and then eyes closed; left leg only, with eyes open and then closed; and right leg only, eyes open and then closed. Tests were carried out with the eyes open and closed because vision has been reported to have an effect on proprioception.[5 8] The order of testing was set out in the computer software, therefore it was impossible to randomise it. Participants stood facing forwards, eyes focused on a point on the wall, arms by sides, for a period of 20 seconds. In the one legged tests, the other knee was bent at 90 degrees to standardise stance position between the subjects. Foot position was standardised, as the subject stood on footplates, the positions of which were marked on a grid and were specific for each person. It has been suggested that there is a period of adjustment in stance[17]; therefore, for each test, there was a timed 10 second interval between initiation of stance on the balance plate and the start of the 10 second measurement phase. The computer sampled data at a frequency of 100 cps for the measurement phase and the SI calculated by the software. At each visit, the series of tests was performed twice in the same order by the same operator. The mean of the two SI values from the two tests was then calculated. Subjects were considered to have failed the tests if they touched the handrails for support once the test had begun.

In addition, at each visit, participants completed the Olerud and Molander questionnaire (fig 1). This gave a score ranging from 0 to 100% of normal ankle function (O&M score). This scoring system has been suggested as a means to make research by different groups into ankle injury more comparable.[18]

DATA ANALYSIS

The mean (SD) of the SI for patients and controls was calculated for each evaluation. The paired *t* test was used to assess differences in SI between the first and second visits, and between the first and third visits, within the same group. The paired *t* test was also used to assess differences in SI between the patients' injured and uninjured legs, and between the controls' right and left legs, at each visit. The two sample *t* test was used to assess differences in the SI between the patients and controls, at each visit. There were participants in both groups that failed to complete either test during the single legged testing with eyes closed. Therefore, for these tests, the number

ANKLE INJURY QUESTIONNAIRE

What follows is a short questionnaire designed to assess the problems which your ankle injury may be causing you. We will combine this information with the data generated by the balance machine. Please select the option that best fits the problems associated with your injury each time you come.

Parameter	Degree	Visit 1	Visit 2	Visit 3	Score
1) PAIN	None				25
	Walking on an uneven surface				20
	Walking on an even surface				10
	Walking indoors				5
	Constant and severe				0
3) STIFFNESS	None				10
	Stiffness				0
3) SWELLING	None				10
	Only evenings				5
	Constant				0
4) STAIRS	No problems				10
	Impaired				5
	Impossible				0
5) RUNNING	Possible				5
	Impossible				0
6) JUMPING	Possible				5
	Impossible				0
7) SQUATTING	No problems				5
	Impossible				0
8) SUPPORTS	None				10
	Taping/wrapping				5
	Stick/crutch				0
9) DAILY LIFE	Same as before injury				20
	Loss of tempo				15
	Change of occupation due to injury				10
	Severely impaired work capacity				0

Figure 1 The Olerud and Molander questionnaire, which was completed by participants at each visit. The version completed by participants had no scoring column present.

of completed balance tests was counted, and presented as a percentage of the total number of tests performed. The Wilcoxon sign rank test was used to assess differences in the number of completed balance tests between the first and second visits, and between the first and third visits, within the same group. The Wilcoxon sign rank test was also used to assess differences in the number of completed balance tests between the patients' injured and uninjured legs, and between the controls' right and left legs, at each visit. The Wilcoxon rank sum test was used to assess differences in the number of completed balance tests between the patients and controls, at each visit. All significance tests were two tailed. $p<0.05$ was regarded as significant. No formal adjustment was made to allow for the multiple tests performed, given the lack of independence of the significance tests.

Results

Over the two years that the study was running, 369 people attended FASIC for the treatment of ankle injuries, and of these 19 matched the criteria required for the study. Table 1 shows

Table 1 Reasons for non-participation in the study

Exclusion factor	*Number (total=350)*
Presented out of time scale	32
Out of age range	
<18	9
>25	215
Other ankle injured	30
Other lower limb, back, or neck injury	64
Balance or vestibular problems	0

Table 2 Demographic data of participants

	Age (years)	*Height (m)*	*Weight (kg)*	*M:F ratio*
Patients	20.4 (1.5)	1.79 (0.08)	74.8 (6.7)	18:1
Controls	21.2 (1.6)	1.73 (0.10)	69.2 (10.6)	8:10

Values are mean (SD).

the exclusion criteria, with the numbers excluded in each case. Tables 2 and 3 give the demographic and sporting data respectively for both groups.

All 18 controls scored 100% on the Olerud and Molander questionnaire at each visit (table 4). None of the patients recorded a 100% score at the first visit, two recorded a 100% score at the second visit, and 12 recorded a 100% score at the third visit. There was a mean improvement in the O&M score of 24.7% between visit 1 and visit 2 ($p<0.0001$), and of 41.3% between visit 1 and visit 3 ($p<0.0001$). These changes were both highly significant.

BOTH LEGS, EYES OPEN (2LEO) AND EYES CLOSED (2LEC)

Table 5 shows the mean SI values for 2LEO and 2LEC testing, and table 6 shows the mean changes in SI between visits for these tests. For 2LEO testing in the patient group, there was a suggestion of an improvement in SI over the three visits, although this was not statistically significant. There were no significant differences between visits in 2LEC testing. For 2LEO testing in the control group, the mean fall in SI was significant between visits 1 and 2, although the overall mean improvement in SI from visit 1 and 3 was very small and not significant. There were no significant changes between visits in 2LEC testing.

Table 3 Details of participants' main sports

Sports	*Patients*	*Controls*
Rugby	1	3
Sailing	0	3
Hockey	2	3
Volleyball	3	0
Orienteering	0	1
Football	7	1
Rowing	2	1
Running	3	0
Climbing	0	1
Archery	0	1
Frisbee	0	1
Squash	0	1
Tennis	1	1
Aerobics	0	1

Table 4 Scores (%) recorded in the Olerud and Molander questionnaire

	Patients (n=19)			*Controls (n=18)*		
	Visit 1	*Visit 2*	*Visit 3*	*Visit 1*	*Visit 2*	*Visit 3*
Mean	56	81	97	100	100	100
SD	18	13	4	0	0	0
Minimum	30	55	90	100	100	100
Maximum	90	100	100	100	100	100

Table 5 Mean sway index values for testing on both legs with eyes open (2LEO) and eyes closed (2LEC)

	Patients (n=19)			*Controls (n=18)*		
	Visit 1	*Visit 2*	*Visit 3*	*Visit 1*	*Visit 2*	*Visit 3*
2LEO						
Mean	0.41	0.32	0.36	0.33	0.27	0.32
SD	0.20	0.12	0.09	0.14	0.10	0.16
2LEC						
Mean	0.46	0.43	0.48	0.39	0.36	0.39
SD	0.21	0.16	0.15	0.17	0.10	0.15

Looking at the changes in mean SI between visits, similar patterns were found for the two groups over the 11 days of testing, for both 2LEO and 2LEC testing. The mean SI for the control group was consistently lower than that for the patient group in both 2LEO and 2LEC testing, although there were no significant differences between the two groups. The mean SI in each group was consistently lower for 2LEO testing than for 2LEC testing within the same group.

SINGLE LEG, EYES OPEN (1LEO)

Table 7 shows mean SI values for 1LEO testing, and table 8 shows mean changes in SI between visits. There were no significant changes in mean SI for the patients' injured or uninjured legs between visits, nor for the controls' left or right legs between visits.

There were no significant differences between the patients' injured and uninjured legs at each visit. For the control group, there was no evidence of any difference between the right and left legs at visits 1 and 2. However, at visit 3, the controls showed a lower mean SI on the left leg compared with the right and this was significant ($p = 0.002$).

For comparison with the patients' injured and uninjured legs, the average of the SI in each of the controls' right and left legs was taken (table 9). Comparing the mean SI for the controls' legs with that of the patients' injured legs, the SI was significantly lower for the control group at visit 1 ($p = 0.009$), although at visits 2 ($p = 0.88$) and 3 ($p = 0.11$) there were no significant differences. Comparing the results for the controls with those of the patients' uninjured legs, there was a significant difference at visit 1 ($p = 0.026$), but not at visits 2 and 3 ($p = 0.10$ and 0.051 respectively).

SINGLE LEG, EYES CLOSED (1LEC)

Table 10 shows the number of tests completed at each visit for 1LEC testing. For the patient group, the pattern over time was similar between the two legs. There were small increases in the number of balance tests completed on each leg between visits 1 and 2, although these were not significant. Between visits 1 and 3, there was a significant increase in the number of balance tests completed on the injured leg ($p = 0.043$). There was a similar increase in completed tests between visits 1 and 3 on the uninjured leg ($p = 0.090$), and although this suggests improvement over time,

Table 6 Mean change in sway index (SI) between visits for testing on two legs with eyes open (2LEO) and eyes closed (2LEC)

	Patients		Controls	
	Between visits 1 and 2	Between visits 1 and 3	Between visits 1 and 2	Between visits 1 and 3
2LEO	−0.09 (p=0.085)	−0.05 (p=0.24)	−0.06 (p=0.0003)	+0.01 (p=0.89)
2LEC	−0.02 (p=0.65)	+0.02 (p=0.78)	−0.03 (p=0.33)	0.00 (p=0.93)

Negative values represent a fall in SI, and positive values represent an increase in SI.

Table 7 Mean sway index for testing in single legged stance with eyes open

	Patients (n=19)			Controls (n=18)		
	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3
ILEO						
Mean	0.74	0.63	0.69	0.58	0.64	0.56
SD	0.19	0.15	0.18	0.17	0.19	0.15
ULEO						
Mean	0.71	0.71	0.71	0.58	0.62	0.64
SD	0.19	0.15	0.19	0.13	0.16	0.17

ILEO, Testing on injured leg with eyes open; ULEO, testing on uninjured leg with eyes open. Controls' left leg was arbitrarily assigned as "injured" leg.

the change was not significant. In the control group, there was a different pattern for the right and left legs in the number of balance tests completed at each visit. More subjects managed to complete two tests and less failed to complete any. No results were significant.

Comparing the injured and uninjured legs within the patient group and the right and left legs within the control group, there were no significant differences between the legs at any visit.

Comparing the results of the average number of tests completed by the controls with the results for the patient group for each leg, significantly fewer tests were completed by the patient group on their uninjured legs than by the control group ($p = 0.004$) at visit 1. At visits 2 and 3, the results suggest a difference between the two, with the patient group completing fewer tests at each visit, although the results are not significant ($p = 0.061$ and 0.077 respectively).

Comparing the number of tests completed for the patients' injured legs with the mean results for the controls, there were some interesting results. At visit 1, the patient group completed far fewer tests successfully and this difference was highly significant ($p = 0.0001$). At visit 2, the patient group was able to complete a greater number of tests than at visit 1, although still significantly fewer ($p = 0.019$) than the control group. At visit 3, the patient group showed further slight improvement, and although there was still a relatively large difference between the two groups, this was not significant ($p = 0.077$).

Table 8 Mean change in sway index (SI) between visits for testing in single legged stance with eyes open

	Patients (n=19)		Controls (n=18)	
	Between visits 1 and 2	Between visits 1 and 3	Between visits 1 and 2	Between visits 1 and 3
ILEO	−0.10 (p=0.074)	−0.06 (p=0.35)	+0.06 (p=0.23)	−0.02 (p=0.61)
ULEO	0.00 (p=0.95)	0.00 (p=0.96)	−0.03 (p=0.35)	−0.06 (p=0.15)

Negative values represent a fall in SI, and positive values represent an increase in SI. Controls' left leg was arbitrarily assigned as "injured" leg.
ILEO, Testing on injured leg with eyes open; ULEO, testing on uninjured leg with eyes open.

Table 9 Difference in mean sway index between the average of the controls' right and left leg with the patient's injured or uninjured leg at each visit

	Visit 1	Visit 2	Visit 3
ILEO			
Mean	0.16	0.00	0.09
SD	0.06	0.05	0.06
p Value	0.009	0.88	0.11
ULEO			
Mean	0.13	0.08	0.12
SD	0.06	0.05	0.06
p Value	0.026	0.10	0.051

ILEO, Testing on injured leg with eyes open; ULEO, testing on uninjured leg with eyes open.

Discussion

The total period of testing spanned two years. Although a large number of patients with ankle injury presented over that time, very few met the inclusion criteria. The exclusion criteria were necessary to minimise any other factors that could affect balance. The control group was picked randomly, with an even ratio of men to women from a variety of sports at the beginning of the study. The ratio in the patient group was 18 men to one woman. The control group was lighter and shorter than the patient group, which may have been attributable to the differences in the male to female ratios between the two groups. It may be that greater numbers of men participate in sports or are greater risk takers than women, thus increasing the likelihood of them injuring their ankles. The control group would have been more comparable if it had been picked at the end of the study with an attempt to match controls by sex and sport with patients, although initially it was hoped that it would have been possible to have sufficient patients to be able to do this.

All of the controls scored 100% on the Olerud and Molander questionnaires at each visit, as would be expected for a group of uninjured subjects. Clinically, it is important for patients to regain full function and sufficient functional stability after ankle sprain to prevent recurrence of injury. The O&M scores reflect the patients' assessment of their injury and as such are purely subjective. In the patient group, there was a highly significant increase in the O&M scores at each visit, and this suggests that the patients themselves perceived an improvement in the function and symptoms in their injured ankles over the period of the study. At the end of the study, 17 patients were back to full activity, although only 12 recorded a 100% score by visit 3. The other five failed to score 100% in the questionnaire, as they noted some residual swelling. We have found clinically that some residual swelling is often present for at least this length of time after an injury, despite the fact that the patient may have returned to sport. Only two of the 19 patients were not back to full activity, with one experiencing pain when walking on uneven ground, and the other being unable to run. Interestingly, the subjective improvement in the patients' symptoms does not coincide with a reduction in the SI values.

The mean SI for 2LEO and 2LEC testing show similar patterns for the two groups, with small mean changes over time and the patient

Table 10 Number of tests completed at each visit for testing on one leg with eyes closed

Number of tests completed out of total of 2	Patients			Controls		
	Visit 1	Visit 2	Visit 3	Visit 1	Visit 2	Visit 3
ILEC						
2	0	4	5	6	12	11
1	5	5	5	9	3	3
0	14	10	9	3	3	4
ULEC						
2	0	5	5	10	6	9
1	7	5	5	3	8	4
0	12	9	9	5	4	5

Controls' left leg was arbitrarily assigned as "injured" leg.
ILEC, testing on injured leg with eyes closed; ULEC, testing on uninjured leg with eyes closed.

group having consistently higher SI than the control group, although this was not statistically significant. This pattern may be clinically important in that it suggests that the injured patients may be functionally less stable as a group.

One would expect to see little change (other than day to day variability) in SI for the control group over the three visits, and this was the case in both 2LEC and 2LEO testing. The small but significant reduction in SI between visits 1 and 2 for the control group in 2LEO testing was unexpected, but may be a function of the small population size and the variability within the group. The fact that the SI results were lower for each group when testing was performed with eyes open rather than shut supports the theory that vision is a contributory factor in balance.

The results for 1LEO testing show, as expected, that there is no change in mean SI for the uninjured leg of the patients. There was a large reduction in mean SI for the injured leg, but only between visits 1 and 2. It may be that the patients were diligent with their balance exercises over the first week and showed considerable improvement, but performed less of them as their ankles improved subjectively (as shown by the O&M scores), and, without sufficient proprioceptive training, functional stability returned to a similar level to that of the uninjured leg at the third visit. In the control group at visit 1, the mean SI value was the same for the right and left legs. The significant change in the mean SI between the right and left leg at visit 3 is not, however, as informative as any change between visits on the same leg; these values were not significant.

Looking at the results for 1LEC testing and comparing the average of the controls' legs with the results for the patients' injured and uninjured legs, there is a large difference between the number of tests completed at visit 1 by the patient group compared with the controls. Even by visit 3, after two weeks of balance training and despite the fact that they were able to complete significantly more tests than at visit 1, the results suggest that the patient group is still functionally less stable, bilaterally, than the control group.

The results suggest that the patient group may have greater postural sway on both the injured and uninjured legs than the control group. This may suggest that some people are more vulnerable to non-traumatic ankle injury. The follow up period of this study was short in terms of monitoring the effects of long term recovery and the effects of a rehabilitation programme, although 17 of the 19 patients were back to full sporting activity at two weeks. It would be useful to carry out further testing at four weeks, eight weeks, and six months to monitor continuing improvement over time and to assess whether with balance training the patient group may become as functionally stable as a control group.

The 1LEC test is often used clinically to assess standing balance, therefore it would be useful to assess any correlation between this test and SI, as measured by the Chattanooga balance machine. This simple clinical test is quick and easily transferable to the "field."

In addition to the balance training exercises, it is possible that there may be a training effect of the testing procedure itself. It would have been preferable to randomise the order of testing to minimise this effect; however, the order of testing was set out in the computer software and it was not possible to alter this.

The lack of statistical significance may be a function of the large variability between and within subjects and the small numbers in this pilot study. Multiple significance testing will have increased the chance of obtaining false positive results and as such any significant differences should be interpreted with caution.

CONCLUSIONS

It can be concluded from this pilot study that, although the patient group improved subjectively, as was shown by the O&M scores, and objectively, as shown in particular by the improvement in the number of tests successfully completed in 1LEC testing, this was not strongly supported by the SI results. The patient group seemed to have greater postural sway on both injured and uninjured legs than the control group and this suggests that some people are more vulnerable to non-traumatic ankle injury.

It could be suggested that the Olerud and Molander questionnaire may have limited use for indicating subjective improvement, although it is necessary to be aware that it could not be used to relate subjective and objective functional stability. It would be useful to investigate the relation between subjective and objective instability as this may then lead to patients being advised not to return to sport too prematurely as they may be at increased risk of a recurring injury.

Further studies would be of benefit with a larger patient group to avoid the high variability encountered between and within our study groups. Any further studies should include long term follow up to determine the role of proprioception in preventing recurrent injury, and to ascertain the effectiveness of physiotherapy in aiding the return to full function. It would also be useful to evaluate a simple test that could be used to screen athletes for postural instability in order that those at risk of ankle injury can be identified and a preventive rehabilitation programme given.

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Take home message
There was a significant subjective improvement in functional standing balance, as measured by the Olerud and Molander questionnaire, over the two week period. There was an improvement in the number of tests completed in single leg, eyes closed testing in the patient group. Further studies would be useful to investigate various aspects of ankle injury and balance.