REVIEW

Rehabilitation of ligamentous ankle injuries: a review of recent studies
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There are many treatment modalities for ankle rehabilitation. These are reviewed, and the most effective training programme for rapid restoration of ankle movement, strength, endurance, and proprioception is selected.

Ligamentous ankle injuries are the most common sports trauma, accounting for 10–30% of all sports injuries. As ankle sprains occur during plantar flexion, supination, and inversion, they are most common in soccer players, but they can also occur in basketball, volleyball and all sports that involve jumping and sidestepping.

Most (85%) ankle injuries are sprains, and only a small percentage are caused by ankle ligament rupture. These injuries originate from the weaker lateral ligaments in up to 85%, and only 3–5% are isolated deltoid ligament sprains.

The high incidence of ligamentous ankle injuries requires clearly defined acute care and a broad knowledge of new methods in rehabilitation. In addition to rapid pain relief, the main objective of treatment is to quickly restore the range of motion of the ankle without any major loss of proprioception, thereby restoring full activity as soon as possible.

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Before outlining recent studies in this field, we would like to describe the standard treatment procedures for ligamentous ankle injuries. Generally, and most importantly, early rehabilitation is regarded as the main aim. Immobilisation in plaster should be reserved for the worst cases as it can result in local irritation, joint stiffness, muscle atrophy, and extensive loss of proprioception. No benefit of surgical repair has been shown over functional treatment with respect to repeat injury or return to function.

Rehabilitation is commonly divided into four phases: the initial phase, early rehabilitation, late rehabilitation, and the functional phase. The duration of each phase depends on the individual healing process.

The initial phase includes analgesic and anti-inflammatoristic effects and the reduction of swelling. This is achieved by rest, elevation, ice in combination with compression, ultrasound and electrotherapy, as well as oral treatment with non-steroidal anti-inflammatory drugs and enzymes. To preserve neuromuscular coordination, it is necessary to start gait training—without weight bearing—as soon as possible.

The early rehabilitation phase aims to restore normal range of motion of the ankle joints using manual treatment and kinetotherapy. Gentle passive movement of the talocrural joint increases range of motion in the sagittal plane; self stretching of the ankle ligamentous system with a towel is useful to increase dorsiflexion. The single planar tilt board or a biomechanical ankle platform system can be used in the sitting position or standing on two legs, and finally on one leg. In addition, cryotherapy and electrotherapy need to be continued to reduce pain and swelling.

When the patient is able to tolerate full weight bearing, the phase of late rehabilitation is reached. The focus of this phase is training of muscle strength and endurance and neuromuscular performance. Isokinetic training is excellent for initial strength training. Based on this, kinetotherapy eliminates proprioception deficits and improves strength and endurance using functional exercises.

The functional phase prepares for a return to full activity and includes jumping and running as well as isokinetic exercises.

LITERATURE SEARCH

Our literature research included electronic databases (MedLine, Embase) from 1966 to April 2002 using the following subject terms: ankle sprain, ankle injuries, sports injuries. We then limited the search using such terms as rehabilitation and proprioception. We also searched the bibliographies of the identified articles. The literature research was carried out in English and German. Following established criteria, levels of evidence are graded as follows: level A, randomised controlled trial/meta-analysis; level B, other evidence; level C, consensus/expert opinion.
A total of 24 articles were identified. Six met the following inclusion criteria: high quality paper (randomised versus non-randomised clinical trial, level A or B) providing primary research data on treatment and rehabilitation. They present specific up to date information on ankle rehabilitation focusing on proprioception and strength training.

We excluded 18 articles: two reviews on ankle rehabilitation and ankle surgery; three articles providing basic knowledge of proprioception and neuromuscular function; one article on varicose veins, bone injuries, diabetes, previous similar injury within 1 year, ankle arthritis, bone injuries, and ankle fractures; one article on ankle sprains, diabetes, and previous ankle surgery; one article dealing with clinical examination; one article on proprioception and neuromuscular function; one article on ankle surgery; three articles providing basic knowledge of ankle rehabilitation focusing on proprioception and strength training.

Table 1: Included studies

<table>
<thead>
<tr>
<th>Study Name</th>
<th>Methods</th>
<th>Participants</th>
<th>Interventions</th>
<th>Measurements</th>
<th>Outcomes</th>
<th>Quality</th>
</tr>
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<tbody>
<tr>
<td>Ashton-Miller et al</td>
<td>Non-randomised clinical trial, 1 group</td>
<td>20 men, mean age 24±4 years Inclusion criteria: No history of ankle injury in the 6 months before testing, shoe size 10</td>
<td>Testing low- and three-quarter-top shoes with and without adhesive tape or one of three orthoses in every subject 2 dynamic groups: strength training varying in dominant/ non-dominant leg, 1 control group: normal activities</td>
<td>Isometric testing: maximal eversion moment</td>
<td>Best protection for a near maximally inverted ankle are strong evertor muscles, improvement in peak torque in the trained and untrained ankle (via crossover effect)</td>
<td>A</td>
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<tr>
<td>Uh et al</td>
<td>Prospective, randomised, controlled study, 3 groups</td>
<td>10 men, 10 women, 18-40 years Inclusion criteria: no history of ankle injury Exclusion criteria: regular medication, regular strength training</td>
<td>Maximal isometric eversion moment developed under full weight bearing with the ankles in 15° of inversion</td>
<td>Isokinetic testing: peak torque, power, endurance</td>
<td>A</td>
<td></td>
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<tr>
<td>Osborne et al</td>
<td>Non-randomised clinical trial, 1 group</td>
<td>10 men and women, 18-45 years Inclusion criteria: non-rehabilitated, unilateral, inversion ankle sprain 6-18 months before study entry</td>
<td>1 dynamic group: ankle disk training on the injured ankle</td>
<td>EMG: muscle onset latency</td>
<td>Decrease of muscle onset latency in specific ankle muscle groups, crossover effect</td>
<td>B</td>
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<tr>
<td>Eils and Rosenbaum</td>
<td>Randomised clinical trial, 2 groups</td>
<td>12 male, 18 female, 14-47 years Inclusion criteria: recent ankle inversion sprains, subjective feeling of giving way Exclusion criteria: pain</td>
<td>1 dynamic group: multistation proprioceptive exercise, 1 control group: normal activities</td>
<td>Joint position sense, postural sway (force plate), EMG: muscle reaction times</td>
<td>Changes in joint position sense, postural sway and muscle reaction time</td>
<td>A</td>
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<tr>
<td>Matsusaka et al</td>
<td>Randomised clinical trial, 2 groups</td>
<td>12 men, 10 women, 18-25 years Inclusion criteria: athletes with functional instability of one ankle Exclusion criteria: fractures of the lower extremity, any impairments of the lower extremity, trunk or central nervous system</td>
<td>2 dynamic groups: ankle disk training, one group with, one group without non-elastic adhesive tape around the lateral malleolus Duration: 6 weeks</td>
<td>Stabilometry: postural sway</td>
<td>Decrease in postural sway</td>
<td>A</td>
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<tr>
<td>Nyanzi et al</td>
<td>Doubleblind randomized controlled trial, 2 groups</td>
<td>30 male and 21 female, 14-65 years Inclusion criteria: sustained injuries less than 100 hours before study entry Exclusion criteria: Previous similar injury within 1 year, sustained multiple injuries, diabetes, varicose veins, bone injuries</td>
<td>1 group: ultrasound therapy for 3 days, 1 placebo group: Duration: 2 weeks</td>
<td>Pain (visual analogue scales), swelling (tape measure), range of movement (fluid filled goniometer), weight bearing (two scales simultaneously)</td>
<td>No better results than placebo</td>
<td>A</td>
</tr>
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</table>

EMG, Electromyography.

STUDY OF ASHTON-MILLER ET AL

“The best “support” for a near maximally inverted ankle at foot strike was found to be fully activated and strong evertor muscles.”

The protection of the inverted weight bearing ankle was investigated by comparing the effect of strong evertor muscles, shoe height, athletic tape, and three different orthoses (evidence level B, non-randomised clinical trial; table 1). Maximal isometric eversion moment developed under full weight bearing with the ankles in 15° of inversion was measured in 20 healthy men, mean age 24 years. Tests were repeated in 0° and 32° of ankle plantar flexion in low top and three quarter top shoes with and without adhesive tape or one of three ankle orthoses. With inactive evertor muscles, a three quarter top shoe increased the baseline resistance to inversion by a factor of 1.42; if the same shoe was worn with a tape or one of the orthoses, the baseline ankle resistance was increased by a factor of 1.77. No significant differences were found in the total eversion moments at 15° of inversion using a tape or a brace with either shoe height. The best “support” for a near maximally inverted ankle at foot strike was found to be fully activated and strong evertor muscles, providing three times greater protection than a tape or orthoses worn inside a three quarter top shoe.

STUDY OF UH ET AL

Uh et al studied the benefit of a single-leg strength training programme for the muscles around the untrained ankle (evidence level A, randomised controlled trial; table 1). They randomised 10 men and 10 women aged 18-40 years, with no history of ankle injury, to a control and a training group. Isokinetic testing of the ankle muscles was performed on both groups at the beginning and end of an eight week study period. Measurements were performed in four directions (dorsiflexion, plantar flexion, inversion, and eversion) and in two modes (concentric and eccentric) at two different speeds (30 and 120°/s). Half of the training group trained the dominant leg only, and the other half trained the non-dominant leg only, three times a week for the eight week period. The control group continued daily activities of living.
The subjects who trained the dominant leg improved peak torque values by 8.5% in the trained leg and 1.5% in the untrained leg. The subjects who trained the non-dominant leg improved peak torque values by 8.5% in the trained leg and 1.5% in the untrained leg. The control group showed no significant change in peak torque, power, or endurance.

**STUDY OF OSBORNE ET AL.**

Osborne et al.²³ investigated the effect of ankle disk training on muscle reaction time in subjects with a history of ankle sprain (evidence level B, non-randomised clinical trial; table 1). Eight minimally symptomatic subjects with a history of non-rehabilitated, unilateral, inversion ankle sprain performed 15 minutes a day of ankle disk training for eight weeks on the previously injured ankle. At study entry and after the training period, both the injured and non-injured leg were tested for ankle inversion perturbation monitored by fine wire electromyography. A significant decrease in the anterior tibialis onset latency was found in both ankles, indicating a proprioceptive cross training effect.
therefore responsible. A period of preactivation is needed to develop sufficient force in the evertor muscles for landing after a jump. When recontact with the ground is earlier than anticipated—for example, when landing on an unseen object—there is inadequate time to prevent forced inversion. In this case, passive devices may help to protect the ankle at 15° of inversion by almost doubling its baseline resistance. The authors attribute the protection afforded by taping only to the stabilising effect; proprioception is not mentioned.

Uhl et al claim to be the first to investigate the effect of muscle training around one ankle on the strength of the muscles around the contralateral ankle. They tried to show a crossover training effect by referring to the evaluations of Komu et al. There are several theories to explain this effect—for example, enhancement of neuromuscular facilitation, the reduction of central inhibitory impulses to the untrained limb, and undetectable isometric contractions of the untrained limb during strength training. The origin of the crossover training effect could not be explained satisfactorily in this study either (as the authors indicate themselves); moreover, the improvements in strength and power were not as impressive as in studies on other joints. However, these results must be seen against the background of the small cohort. The authors plan to carry out further research with larger numbers of subjects. In addition, it would be interesting to investigate patients with a history of ankle injury.

Some kind of crossover effect was also identified in the study of Osborne et al. They succeeded in demonstrating the effects of proprioceptive crossover training. A previous study dealt with muscle onset latency: patients with uninjured ankles showed an increase in onset latency of both the anterior tibialis and posterior tibialis muscle. These results are in contrast with those presented in the more recent study, in which the anterior tibialis muscle showed a significant decrease in onset latency. The reason for this difference in finding effects in patient groups with or without a history of ankle injuries is unclear. Further research on this that also investigates other muscle function parameters and considers complex physiological adaptations is required.

The strength of the study of Eils and Rosenbaum lies in its broad methodological approach. The test design included three different testing procedures before and after the training period and, in addition, the results were re-evaluated one year after training. The three test procedures allowed an overview of multiple factors influenced by ankle training in a single study. The re-evaluation was of particular interest because recurrent instability has been estimated to occur in 10–20% of patients irrespective of the type of initial treatment. Strength training in combination with proprioception training is the generally accepted programme for complex rehabilitation. Furthermore, it appears to be the only study in recent years in which patients performed circuit training in a large group. Besides the documented clinical benefits, this group training may prove to be highly cost effective.

Matsusaka et al also investigated the efficacy of proprioception training. The experimental conditions were based on the finding that ankle taping has more than just a supportive function; the adhesive tape, placed on the area where the sural nerve provides cutaneous branches to the lateral side of the leg and foot, stimulates by traction the skin receptors during postural correction on the ankle disk. In this way, the disturbance of the afferent input from mechanoreceptors in the injured ligaments and capsule of the functionally unstable ankle is compensated. The mechanism of this process is not elucidated by this study, but the results show that a combination of ankle disk training and non-elastic adhesive tape have a better effect on postural sway than applying only one of the methods.

The study of Nyanzi et al shows no significant results. Despite this, we thought it worthy of mention because it has been suggested that ultrasound treatment improves the rate and quality of healing and reduces pain. The diversity of

**STUDY OF EILS AND ROSENBAUM**

Eils and Rosenbaum studied the effects of a six week multistation, low frequency exercise programme (evidence level A, randomised controlled trial; table 1). They randomised 30 subjects (18 male and 12 female) with chronic ankle instability, repeated ankle inversion sprains, or a subjective feeling of instability or giving way to an exercise group or a control group. The control group were tested before and after the six week period but did no exercise. The exercise group followed a physiotherapy programme consisting of 12 different exercises including both strength and proprioception training in the form of circuit training for 20 minutes once a week. Joint position sense, postural sway, and muscle reaction times were tested using a trap door and surface electromyography. After the six week training period, improvements in the ankle reproduction test were found in the exercise group for all the test conditions. In the postural sway test, both groups improved for all parameters. Muscle reaction times were prolonged in both groups for all muscles. Integrated electromyography showed only a slight decrease for the tibialis anterior muscle in the experimental group. A questionnaire returned one year after training showed a significantly (almost 60%) reduced incidence of ankle inversions after the exercise programme.

**STUDY OF MATSUSAKA ET AL**

Matsusaka et al tested the combination of ankle disk training and tactile stimulation (evidence level A, randomised controlled trial; table 1). Twenty two students with unilateral functional instability were randomised to two experimental groups, both of which trained to stand on the affected limb on an ankle disk. Subjects in group 1 trained with two pieces of 1 cm wide non-elastic adhesive tape applied to the skin around the lateral malleolus from the distal third of the lower leg to the sole of the foot. The other group trained without the adhesive tape. Before, during, and after the 10 week training programme (10 minutes a day, 5 times a week), postural sway was tested in all subjects standing on the affected limb. Postural sway values for group 1 had decreased significantly after four weeks. After six weeks of training they were within the normal range. In contrast, the values in group 2 did not significantly improve and they were not within the normal range until after eight weeks of training.

**STUDY OF NYANZI ET AL**

Nyanzi et al examined the use of ultrasound compared with placebo (evidence level A, randomised controlled trial; table 1). They included 51 patients with injuries sustained less than 100 hours before entry within the age range 14–65 years and randomised them to two groups. One group had ultrasound treatment at an intensity of 0.25 W/cm² at a mark space ratio of 1:4 at 3 MHZ for 10 minutes per session. The placebo group was not aware that the ultrasound machine was in its sham phase. Treatment was given on three consecutive days. Both groups wore Tubigrip (Seton, UK) after treatment. All patients were measured on every day of the treatment period and for 14 days after the end of treatment, using a visual analogue scale to assess pain, tape measurement of the ankle to record swelling, range of motion to determine mobility, and simultaneous weighing to assess ability to weight bear. No significant differences in any outcome measure were found between the groups.

**DISCUSSION**

Ashton-Miller et al showed that no external support can provide the same degree of protection as strong evertor muscles. However, it may happen that the evertor muscles fail to prevent an ankle inversion injury. The muscle onset latency is therefore responsible. A period of preactivation is needed to develop sufficient force in the evertor muscles for landing after a jump. When recontact with the ground is earlier than anticipated—for example, when landing on an unseen object—there is inadequate time to prevent forced inversion. In this case, passive devices may help to protect the ankle at 15° of inversion by almost doubling its baseline resistance. The authors attribute the protection afforded by taping only to the stabilising effect; proprioception is not mentioned.

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**Take home message**

A combination of isokinetic strength training with proprioception training shortens rehabilitation and serves as secondary prophylaxis.

measurements included major clinical features of ankle sprains such as pain, swelling, and reduced mobility. Nevertheless, as the authors indicate, treatment using the dose and duration specified did not lead to significant results.

**Conclusion**

Improvement in proprioception is important in ankle rehabilitation and this should be taken into consideration when setting up a rehabilitation programme. Furthermore, it has been shown that a combination of different exercises leads to better results and allows earlier return to the activities of daily life. The most efficient method of restoring range of motion and proprioception seems to be ankle disk training together with taping. In addition, isokinetic training increases the strength of the injured leg as well as that of the uninjured leg by the crossover training effect.

**References**

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