

## Quantitative assessment of mechanical ankle laxity using MR imaging

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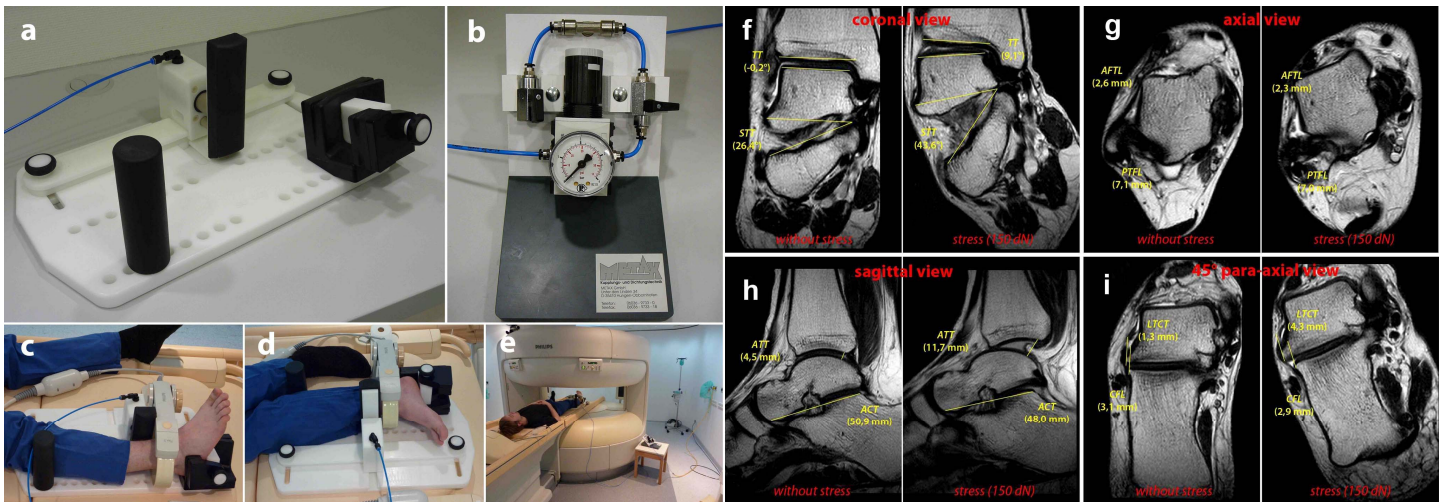
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**Introduction:** Lateral ankle sprains are the most common musculoskeletal injuries acquired during physical activity and daily life. For the physician, chronic ankle instability (CAI) still remains a controversial entity, as the ankle is a complex joint with contributions from the talocrural and subtalar joints, and diagnosis is usually difficult. Stress radiography using X-ray commonly is used to assess disorders of the ankle in patients with a history of ankle sprain. No reports have been documented so far combining the advantages of MRI with ankle stress examination. The purpose of this study was to determine feasibility and value of ankle stress examination using MR imaging.

**Material and Methods:** An MR-compatible stress device was developed (Telos, Hungen, Germany) and tested for safety and applicability in MR environment (ASTM F2052-06; NEMA MS 1-2008). Based on the results of previously collected subjective instability parameters of 50 volunteers using different ankle scores (Ankle Activity Score, Lysholm Score, FAOS (Foot and Ankle Outcome Score)) functional ankle instability (FAI) was assessed. Hereafter, the volunteers were assigned to group A (stable) and B (unstable). 72 ankle joints of 37 healthy patients were included in group A (20 male, 17 female, mean age 30.9 years, age range 20 to 51 years, mean BMI 23.8, BMI range 18.4 to 30.6) and compared to 28 ankle joints of 15 patients suffering from CAI in group B (10 male, 5 female, mean age 30.4 years, age range 20 to 54 years, mean BMI 24.5, BMI range 20.7 to 28.4). Measurements were performed in a 1T open MRI (Philips, Eindhoven, NL). T2w FSE sequences (TE: 100 ms, TR: 3309 ms, slice thickness: 3 mm) were performed in coronal, sagittal and axial slice orientation during simulation of lateral inversion stress and anterior drawer test. The talar tilt (TT), subtalar tilt (STT), anterior talus translation (ATT), anterior calcaneus translation (ACT), the lateral translation of talus and calcaneus (LTCT) and the ligaments of the lateral ankle (ATFL, CFL, PTFL) were assessed with a 15 kp stress challenge (Figure 1).

**Results:** The talocrural as well as the subtalar joint could be assessed simultaneously in coronal images and allowed direct differentiation of tilt differences between talocrural and subtalar joint. The TT in group A was  $2.7 \pm 1.3^\circ$  (m) and  $4.4 \pm 1.5^\circ$  (f); in group B the TT was  $8.9 \pm 6.7^\circ$  (m) and  $4.8 \pm 3.4^\circ$  (f). The STT in group A was  $4.8 \pm 2.7^\circ$  (m) and  $6.4 \pm 2.5^\circ$  (f);  $6.2 \pm 3.7^\circ$  (m) and  $14.3 \pm 2.2^\circ$  (f) in group B. Statistically significant differences between group A and B ( $p < .001$ ) and statistically significant gender differences in group A ( $p < .001$ ) could be found for the TT and STT. The ATT in group A was  $1.7 \pm 0.8$  mm (m) and  $2.5 \pm 1.1$  mm (f); and  $3.6 \pm 1.6$  mm (m) and  $3.2 \pm 2.8$  mm (f) in group B. For the ATT, statistically significant differences between group A and B ( $p < .05$ ) and statistically significant gender differences in group A were found. The ACT in group A was  $0.9 \pm 0.6$  mm (m) and  $1.1 \pm 0.7$  mm (f); and  $1.8 \pm 1.3$  mm (m) and  $1.9 \pm 0.9$  mm (f) in Group B. There were statistically significant differences between group A and B ( $p < .001$ ). In addition, a statistically significant difference was found between group A and B ( $p < .003$ ) for the LTCT. A correlation was found for the TT/ATT in group A ( $r = .3$ ) and group B ( $r = .4$ ); as well as for the STT/ACT ( $r = .4$ ) and STT/LTCT ( $r = .5$ ) in group B. A significant gender difference ( $p < .05$ ) was found for the ATFL, CFL and PTFL in ligament thickness and thickness decrease in group A.

**Conclusion:** The MR-stress radiography offers new possibilities in diagnosis of chronic instability of the ankle joint. The direct assessment of ligaments under stress challenge and differentiation between instability of the talocrural and subtalar joints are advantages compared to common stress tests. Not only MR stress assessments of the ankle, but also stress tests of the knee joint are now possible and offer progress in diagnosis of instability of the ankle and knee joint without x-ray exposure.



**Figure 1:** The figure shows the MR-compatible stress device consisting of a stress unit (a) and a control unit (b). The stress unit (a) measures 53 x 30 x 21 cm and is made up of a synthetic base plate, a carbon fibre abutment with sponge rubber batting, a synthetic foot holding apparatus and a pneumatic pressure applicator. The control unit (b) is connected to the pressure applicator and the standard clinical in-room compressed air port with 5 mm synthetic tubing and consists of a manometer and two manually operated pressure valves for controlled stress application. A ring coil (Multi purpose S, Philips Healthcare, Eindhoven, The Netherlands) was used for imaging and was positioned at the level of the talocrural joint (c+d). Stress tests were performed to simulate inversion stress (c) and anterior drawer tests (d). Figures c-e show the stress device within the MRI (Panorama HFO, Philips Healthcare, Eindhoven, The Netherlands). The control unit could be placed directly inside the scanner; no clinically relevant attractive forces occurred (e). The figures f-i illustrates additional diagnostically and clinically relevant information provided by stress examination using MR imaging compared to x-ray and shows the principle measurements for TT, STT, ATT, ACT, LTCT, AFLL, CFL and PTFL in an example of a unstable ankle joint.