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## Too lax: Mechanical ankle instability impairs joint control in the ankle sprains mechanism

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### INTRODUCTION

Lateral ankle sprains belong to the most common injuries in sports and can result in chronic ankle instability (CAI) with residual symptoms like recurrent ankle sprains, 'giving-way', pain or swelling [1]. In order to develop effective preventive and rehabilitative measures against lateral ankle sprains and CAI, it is important to get a detailed understanding of the related injury mechanisms and risk factors. However, despite much research, current knowledge about neuromusculoskeletal impairments in individuals with CAI is limited [3]. It remains an open question how mechanical ankle instability (MAI), i.e., an excessive inversion/anterior laxity, and functional ankle instability (FAI), i.e., subjectively perceived instability, affect joint control in the ankle sprain mechanism.

The purpose of the present study was to evaluate if individuals with MAI have an impaired ankle joint control in injury-like situations compared to individuals with FAI and healthy controls.

### METHODS

317 volunteers were evaluated concerning their ankle sprain history, FAI and MAI.

FAI was assessed by the use of the Cumberland Ankle Instability Tool (CAIT), which was shown to be a valid questionnaire to measure the perceived ankle instability during sportive and daily life activities [1].

The mechanical stability of the ankle joint complex was assessed by an experienced orthopedic, who was blinded to the injury history and the CAIT results. Performing a manual examination (anterior talar drawer and talar tilt) each ankle was categorized as 'definitely stable', 'potentially unstable', or 'definitely unstable'.

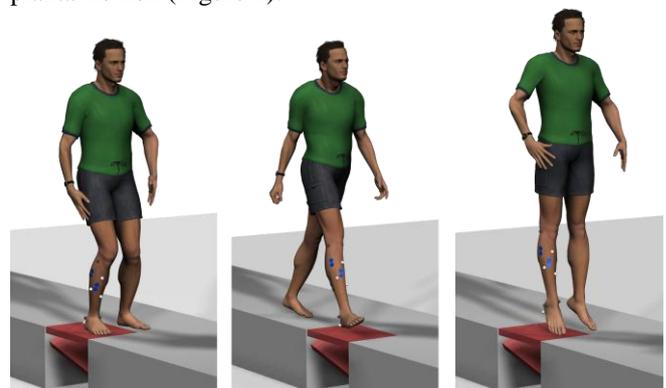
Following this procedure 271 volunteers were excluded and the remaining 46 individuals were categorized in the following three groups:

RS+FAI+MAI (n=19): individuals with recurrent sprain within the last two years ( $n \geq 2$ ), being considered as having FAI (CAIT-score  $\leq 24$ ), and being categorized as MAI ('definitely unstable').

RS+FAI (n=9): individuals with recurrent sprain within the last two years ( $n \geq 2$ ), being considered as having FAI (CAIT-score  $\leq 24$ ) but without MAI ('definitely stable').

CON (n=18): healthy controls without an ankle sprain history, without FAI (CAIT-score  $\geq 28$ ), and without MAI ('definitely stable').

In the experimental measurement the ankle sprain mechanism was imitated under standing, walking and hopping conditions using a custom built platform, which was able to induce a deflection of 24° inversion and 15° plantarflexion (Figure 1).



**Figure 1:** Imitating the ankle sprain mechanism in the standing, walking and hopping subject (start and end position of the tilt-platform are illustrated in red).

A three-dimensional motion analysis of the ankle joint complex was performed at 240Hz (Vicon Motion Systems, Oxford, UK). Retro-reflective marker clusters attached at the calcaneus and the shank allowed for the calculation of plantar/dorsiflexion, inversion/eversion, and internal/external rotation. Joint angles before tilting the platform, maximum angular excursions and angular velocities were extracted.

Moreover, the muscle activities of the m. tibialis anterior and the m. peroneus longus were assessed using wireless surface electromyography at 2400Hz (myon RFTD-E08, myon AG, Baar, Switzerland). RMS values in the phase before ground contact (100ms) as well as after initiation of the tilt (0-60ms, 60-90ms, 90-120ms) were assessed to evaluate the neuromuscular activation.

An analysis of variance with a between-group factor 'group' (RS+FAI+MAI, RS+FAI, CON) and with a repeated-measured factor 'condition' (standing, walking, hopping) was performed. Post-hoc t-tests were Bonferroni corrected.  $P < 0.05$  was considered as statistically significant.

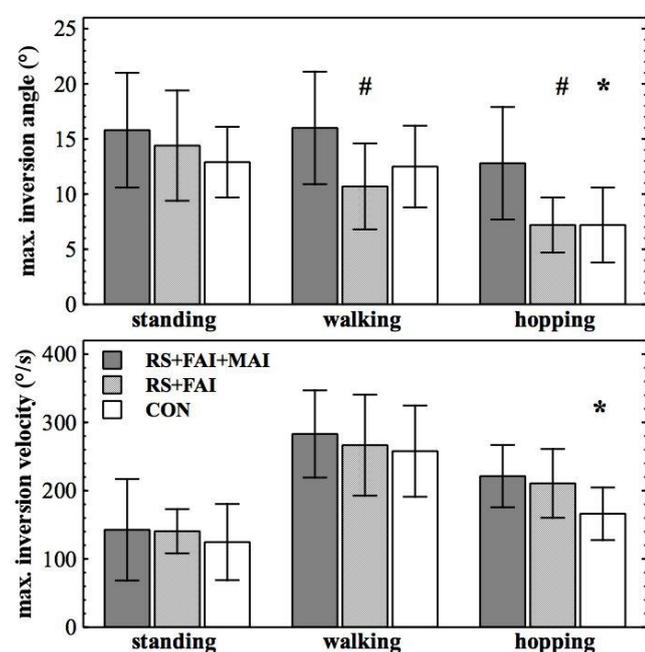
### RESULTS AND DISCUSSION

The maximum ankle inversion when tilting the platform was different between groups ( $p=0.004$ ;  $\eta^2=0.23$ ) and showed a group x condition effect ( $p=0.020$ ;  $\eta^2=0.13$ ). Post-hoc

analysis revealed that the maximum ankle inversion was considerably increased in RS+FAI+MAI in the walking (+3.5°;  $p=0.058$ ) and hopping condition (+5.5°;  $p=0.001$ ) compared to CON (Figure 2, top panel). Similarly, RS+FAI+MAI showed a higher maximum inversion angle compared to RS+FAI in the perturbed walking (+5.3°;  $p=0.013$ ) and hopping subject (+5.6°;  $p=0.004$ ). No differences between groups were found in the standing condition (for all  $p>0.18$ ).

Moreover, there was a significant difference between groups for the maximum inversion angular velocity ( $p=0.032$ ;  $\eta^2=0.15$ ). Compared to CON, the inversion angular velocities were increased in RS+FAI by 45°/s ( $p=0.055$ ) and in RS+FAI+MAI by 55°/s ( $p=0.002$ ) in the hopping condition (Figure 2, bottom panel).

No significant group or group x condition effects were found for ankle plantarflexion or internal rotation (for all  $p>0.2$ ;  $\eta^2<0.06$ ).



**Figure 2:** Maximum inversion angles and inversion angular velocities (Mean±SD). \* denotes a significant difference between RS+FAI+MAI and CON. # denotes a significant difference between RS+FAI+MAI and RS+FAI.

The m. peroneus longus preactivation before ground contact was different between groups ( $p=0.021$ ;  $\eta^2=0.17$ ). RS+FAI+MAI showed a trend towards a decreased preactivation in the walking condition ( $p=0.061$ ) and a significant decrease in the hopping condition ( $p=0.021$ ) compared to RS+FAI.

No significant difference was detected for all other analysed parameters, i.e., for the m. tibialis anterior and for the EMG after tilting the platform.

The results of the present study provide important information extending the current knowledge on CAI:

First, individuals with MAI were exposed to an increased and faster ankle inversion in a close-to-injury situation compared to healthy controls and individuals with pure FAI. This clearly indicates that mechanical impairments destabilize the ankle joint complex in the lateral ankle sprain mechanism and make sprain occurrences more likely. In

consequence, it seems reasonable to assume that additional mechanical support, e.g., external ankle brace or even surgery, should compensate for the mechanical deficits in this specific subgroup of CAI.

Second, only the ankle inversion discriminated MAI and non-MAI although the imitation of the sprain mechanism resulted in high deflections in plantarflexion and internal rotation (up to 450°/s) in all test conditions as well. Hence, it is thought that specifically the frontal plane ankle joint stabilization is affected in MAI, presumably due to the compromised lateral ankle ligament complex resulting from recurrent ankle sprains.

Third, individuals with MAI had a decreased m. peroneus longus preactivation compared to individuals with pure FAI. A decreased preactivation is likely to reduce the sensitive of the muscle spindle and thus can reduce stretch responsiveness [4]. Assuming an increased stretch load in MAI due to the increase in ankle inversion, the decreased preactivation may therefore explain why the subsequent reactive neuromuscular response after the tilt was not increased in MAI. This implies that the neuromuscular system was adapted to the altered mechanical situation found in individuals with MAI. Although the clinical relevance of this observation remains ambiguous, it indicates that holistic neuromusculoskeletal approaches are needed to evaluate the impairments of CAI and its subgroups.

Finally, differences in joint excursion and neuromuscular activation pattern were only observable in the walking and hopping conditions. It is suggested that simulating the ankle sprain mechanism in the standing subject alone is not functional enough (e.g., no integration of feedforward control mechanisms) to elucidate for differences between groups [2]. More functional approaches, like simulating the ankle sprain mechanism in the acting subject as done in the present study, may help to further evaluate biomechanical and neuromuscular impairments in individuals with CAI.

## CONCLUSIONS

CAI is often associated with a mechanical instability of the ankle joint complex. The present study clearly demonstrates that individuals with MAI are exposed to an increased inversion in the ankle sprain mechanism compared to persons with stable ankles. This probably makes them more prone to sprain their ankle and asks for additional mechanical support for individuals with MAI.

In addition, the present study highlights that complex neuromusculoskeletal approaches and functional experimental test conditions are needed to further unravel the mystery of CAI.

## ACKNOWLEDGEMENTS

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