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The Effect of Dynamic Carbon Insoles in Running Sports

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Background: This study was carried out to examine the benefits of dynamic carbon insoles for runners suffering from Achilles tendon pain or knee pain. Materials and Methods: A treadmill analysis was performed in 26 subjects. The effects of carbon insoles on hip rotation and foot stresses in the shoe were then determined. The data were recorded by the MyoMotion (Noraxon) inertial sensor system and the vebitoSCIENCE (Vebito) insole measurement system. Results: The results showed that hip internal rotation and ankle eversion were reduced in male and female subjects by the insole. The bending and torsional moments at the heel and the metatarsophalangeal joint (MTP) 5 were also reduced. No significant effect on foot stress at MTP 1 was detected. Conclusion: A treadmill analysis is highly recommended for athletes with specific symptoms. Carbon insoles can optimise the runner's gait pattern regarding bending and torsional stress at the foot, ankle motion, and hip rotation.

Key words: carbon insole, treadmill analysis, running, Achilles tendon pain, patellofemoral pain syndrome

Introduction

Running is great. People of all ages, at all levels of training and from all segments of the population run. It is the natural form of movement and many have discovered this sport in recent years. Although many individuals take up running, only a few of them keep at it. Athletes often complain of orthopaedic problems that make running difficult.

Comprehensive running and movement analyses are the basis for optimal care. Many athletes decide to have a running analysis because of recurring pain at or around the knee joint or Achilles tendon. The most common diagnosis for pain located in the patella, the patellar groove and connective tissue is the patellofemoral pain syndrome (PFPS). Achilles tendon pain frequently stems from the severe stress to the Achilles tendon caused by running.

Previous studies have examined the causes of pain and found a relation to increased internal rotation of the hips and instability of the subtalar joint [1, 2, 3]. This gives rise to the question of how these factors can be positively affected by fast, practical care.

Additionally, Kraus showed back in 1973 that statics and load bearing capacity of the arch of the foot depend, among other things, on the arch rise. "Flat feet with a low arch put more strain on plantar tension than feet with high arches, i.e. they have a greater tendency to deformation," said Kraus [4]. The height of the arch also depends on the position of the rearfoot. The position of the rearfoot in turn is affected by the size and vector of forces arising from the different individual and also pathological static and kinetic properties of the entire lower limb. Every analysis of the statics of the foot must therefore include the entire pelvis-leg statics.

Hohmann et al. described in 2004 that all movements in the ankle joints are possible only as combination movements due to the oblique movement axes of the joints: "An inward rotation of the lower leg under loading causes compensatory movement of the talus in plantar-medial direction, the plantar surface moves to relative abduction, the heel to pronation, and the medial longitudinal arch of the foot flattens considerably under supination of the forefoot. The outward rotation of the lower leg reverses this process." said Hohmann [5]. When walking, the lower leg is rotated outward at the time of heel strike. Under full loading in the stance phase, the lower leg rotates inward. In the toe-off phase, the lower leg rotates outward again as knee extension increases and the foot can straighten again.

It is already known that both hobby and professional runners saw a positive change in their conditions after being fitted with a dynamic carbon insole from Medi. Hence, the objective of this study was to examine the effect of the shell insole with a carbon clip on the internal rotation of the hips, ankle eversion and thus on the inward rotation of the lower leg. It examines the hypothesis that the insole can reduce these parameters to have a positive effect on the causes of pain in individuals with knee and ankle pain [1, 2, 3].

Material and methods

Subjects

To compile the measurement data, running analyses were conducted in 26 subjects (male: n = 12, female: n = 14). The arithmetic mean age was 29.5 ± 9.5 years, weight 69.5 ± 15.5 kg and height 1.77 ± 0.12 m. The subjects reported different levels of fitness. Exclusion criteria were injuries within the last six months, impaired joint mobility and a pathologically conspicuous gait. Some 21 of 26 subjects reported having experienced pain in the patellar region at least once during running training.

Carbon insole

The carbon insole is a shoe insole in the form of a shell (Fig. 1). The underside of the insole has a 0.8 mm thick carbon clip (model "Igli Allround light C+" from Medi). The carbon clip has torsion sections at the level of the sustentacalum tali and in the forefoot area to facilitate physiological rollover. Due to the sections and the resilience of the material, the insole does not have the effect of a rigid object that immobilises the joints in the foot. Instead, the effect should be to activate the muscles of the lower limbs. The top of the insole is a 4 mm layer of EVA 35° Shore A with a velour cover. Below the carbon clip, a 2 mm thickness of EVA 50° Shore A was used.

The insole was tested in a "Makai" neutral shoe from Zoot. Zoot produces the midsole of the women's shoe with a drop of 11.5 mm, the midsole of the men's shoe with a drop of 13.1 mm.

Inertial sensor system

"MyoMotion"

"MyoMotion" (Noraxon) is a camera-free, transportable, 3D kinematic system able to capture human movement in three degrees of freedom. It consists of a combination of hardware (inertial sensors) and the MyoResearch MR3 software. By positioning the inertial sensors at adjacent segments of the body, their spatial orientation is registered and the range of movement of the joint between them is determined. The data measured are transmitted wirelessly to a receiver and analysed by the MR3 software.

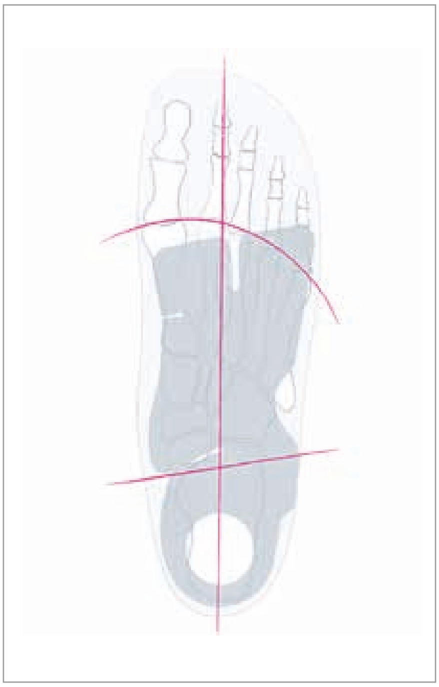

Fig. 1 Technical illustration of the Igli carbon clip with torsion sections.

Inner sole measurement system (ISM) "vebitoSCIENCE"

The "vebitoSCIENCE" measuring system developed in the biomechanics laboratory at the Münster University of Applied Sciences is a combination of hardware (measuring soles) and software for the purpose of determining multidimensional stresses acting on the foot in shoes. Kerkhoff et al. published initial studies in 2014 that showed that "the (...) inner sole system allows the fast, easy, and reliable testing of orthopaedic devices using mobile bending and torsional load measurements" [6].

The "vebitoSCIENCE" hardware consists of a data transfer unit for the wireless transfer of measurement data to the software and insoles, each with five integrated measuring sites for measuring loads. The carrier layer of the measurement soles consists of a specially formed elastic material onto which strain gauge sensors (Vishay) are attached. The measuring sites are located proximal to the distal interphalangeal joints 1 and 5 (DIP 1, DIP 5), proximal to the metatarsophalangeal joints 1 and 5 (MTP 1, MTP 5) and distal to the calcaneal process (heel).

The multidimensional foot stresses include bending strains such as the strain of the forefoot to the rearfoot at the transition from the mid to the terminal stance phase caused by bending moments. Physically, bending moments are defined as the product of the force acting and the length of the lever arm. Torsion describes the twisting of a body, for example twisting of the foot around its longitudinal axis.

Test procedure

Prior to measurement, the age, height, weight, fitness level, and injury history are taken for every subject and documented in a short form. To determine limitation of movement in the ankles and conspicuities in the gait, the neutral-null method was used and an initial barefoot measurement was conducted on a slat belt treadmill (Woodway).

Every subject warmed up for 3 minutes without sensors to become familiar with the treadmill. The subjects selected different speeds between 8 km/h and 10 km/h. In the barefoot measurement that followed, the inertial sensors were used to record the angles. For the following measurements, the subjects wore the neutral shoe including the inner sole measuring system (ISM). The measurements were made with and without the insole and in random order. For the measurement with the carbon insole, the original sole of the shoe was removed to make space and replaced with the trimmed-to-size insole. The ISM was placed on the insoles. All sensors and the ISM were placed by the same person for the measurements and the position was checked after every measurement (Fig. 2).

Analysis

For the analysis, the mean was formed from 20 strides extracted from every measurement. The statistical analysis of the data collected was made using the SPSS software from IBM. The software was used in the study to check the maximum and minimum values measured for statistical significance. The significance level was specified as $p = 0.05$.

The measurement data of women and men were analysed separately, as Kerkhoff et al. found gender-specific differences in running style and foot loads in previous studies [7] and also because the drop of the shoes differed.

Results

The diagrams in Figures 3 to 8 show the analyses of the angle and load measurements. The calculated mean values and the maximum and minimum value of a subject are presented for barefoot measurement (B), measurement without insole (w/oI) and measurement with insole (wI). The greatest variance resulted from the different speed selected by each subject. The term "range" below describes the range of movement or the difference between the external rotation and internal rotation moments.

The running shoe alone had no statistically significant effect (sm = 0.211, sf = 0.421) for male and female subjects Eversion (Fig. 3, 4) was reduced significantly with the insole by about 1.5° in both groups of subjects (sm = 0.001, sf = 0.017). The reduction of the range of movement was statistically significant only for the male subjects (sm = 0.002, sf = 3.309).

The comparison of the hip rotation

Fig. 2 *Fixation of the measuring systems and calibration.*

angle (Fig. 5, 6) shows that the neutral shoe had no significant effect on the internal rotation of the hip (sm = 0.289, sf = 0.758). The hip external rotation was also unchanged by the carbon insole (sm = 0.502, sf = 0.755). However, internal rotation was reduced by the insole from 7.03° to 5.83° in male subjects (sm = 0.005). The combination of shoe and insole compared with barefoot resulted in a reduction of the internal rotation angle by 2.48° (sm = 0.001). Hip internal rotation is reduced by the insole from 3.26° to 1.55° in the female subjects (sf = 0.045). The increased internal rotation with the shoe was not statistically significant for the female subjects (sf = 0.758). The range of movement was also not significantly affected by any of the conditions. In measurements with the insole, the comparisons of the torsion moment measurements at the heel measuring site (Fig. 7, 8) were statistically significant only for the internal rotation moment and range. The mean internal rotation moment was reduced with the insole by 15.00 Nmm to 5.56 Nmm in male subjects (sm = 0.031). The range between the external and internal rotation moment was reduced by 6.6 Nmm (sm = 0.047). For the female subjects, the internal rotation moment was reduced with the insole from 22.75 Nmm to 10.42 Nmm (sf = 0.001). As a result, the range was 21.17 Nmm smaller (sf = 0.000).

Discussion

Ankle joint

The limitation of eversion by the insole was proven by the angle measurements (Fig. 3, 4). The eversion angle was significantly reduced by the insole, while there was no significant change to the inversion angle. Merely moving without changing the angle would result in putting the rearfoot in supination deformation. These results show that the insole does not force the foot to overcorrect, but only compensates for hyperpronation with specific support.

The values of the torsion moment measurements at the heel (Fig. 7, 8) serve to clarify these results. The fewer torsion moments acting at the heel, the less change in the axis and position of the rearfoot to the forefoot there is and the lower the tensile and friction forces

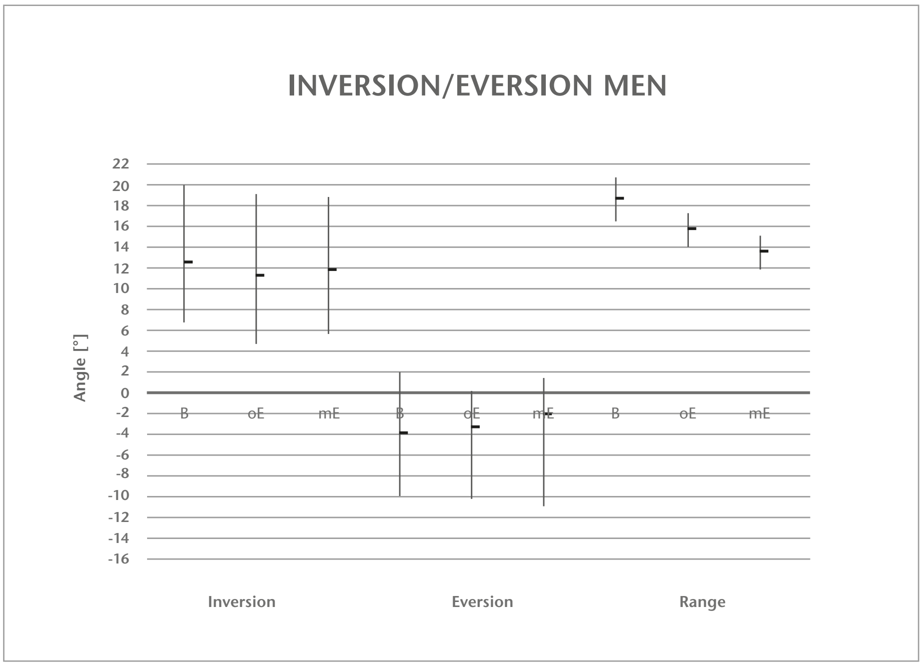

Fig. 3 *Inversion/eversion men.*

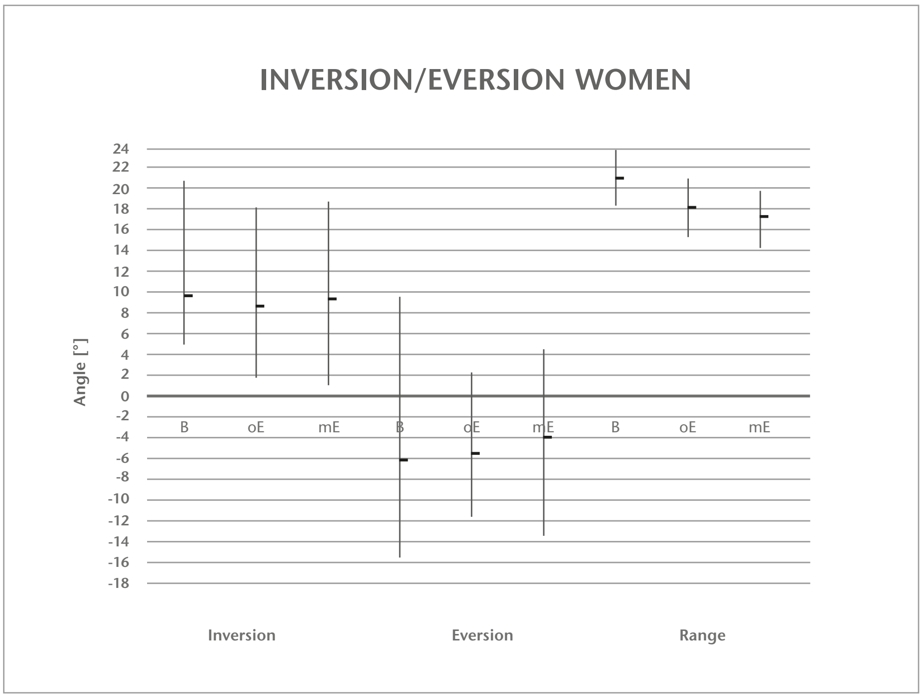

Fig. 4 *Inversion/eversion women.*

acting on the Achilles tendon are. With vebitosolution, a significant reduction of more than 50% of the load at the heel due to internal rotation moments was found for both groups of subjects. Overall, the difference between external and internal rotation moments was smaller when the subjects wore carbon insoles. Smaller dorsal extension moments were also found at the same measuring site. This indicates lower loads on the short muscles of the foot, the tendons of the long muscles of the foot and especially on the plantar aponeurosis, which support the longitudinal arch.

The carbon slip integrated into the shell insole has a torsion section medial between the calcaneus and the tarsal bones that extends approximately up to the longitudinal axis of the foot. On the lateral side, the insole is stable due to the full-length carbon. The purpose of the torsion sections is to support natural rollover and prevent compensatory movement toward genu varum. As both the dorsal extension moments and the external rotation moments at MTP 5 are reduced by the insole, compensatory movement can be prevented. No statistically significant changes due to wearing the insole were found at MTP 1, which leads to the conclusion that it continues to allow physiological rollover over the first ray.

These results proved the positive effect of the dynamic carbon insole on the factors identified as possible causes for Achilles tendon pain or injuries and the patellofemoral pain syndrome in the studies by Lorimer et al. [1], Reule et al. [2] and Souza et al. [3].

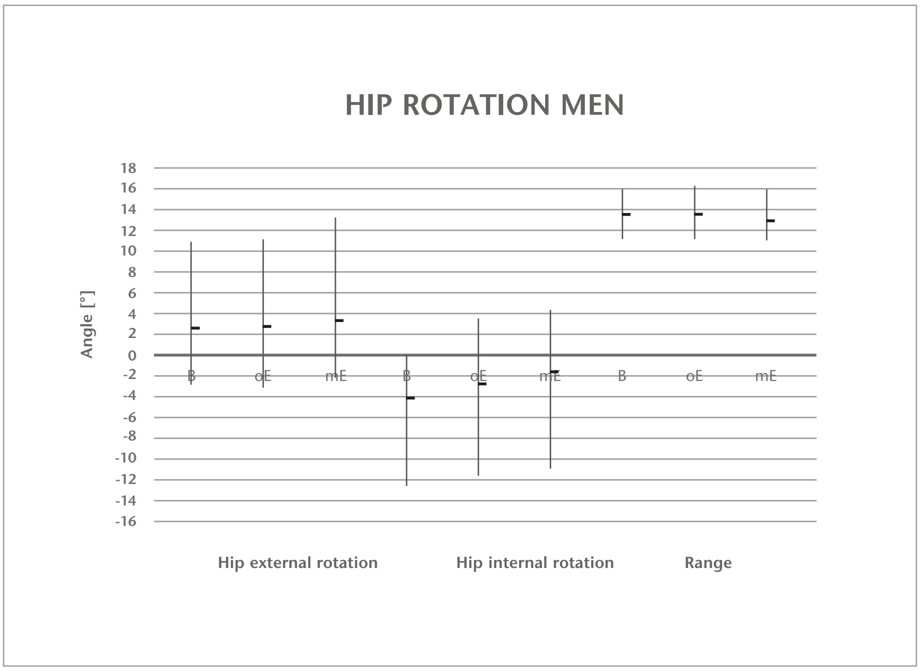

Fig. 5 Hip rotation men.

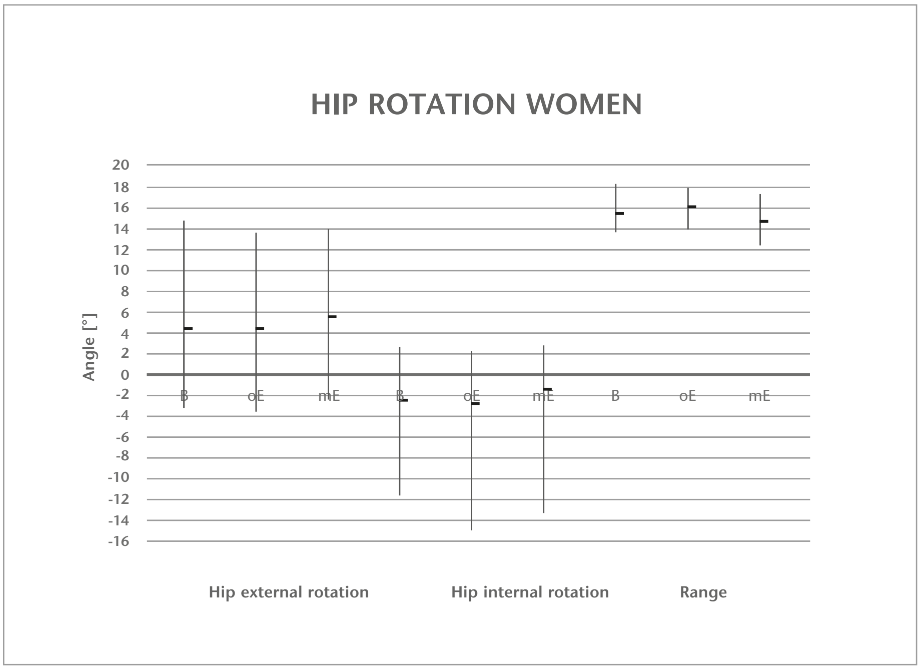

Fig. 6 Hip rotation women.

Hip

The second parameter to be studied was the reduction of hip internal rotation when running. The results show only little variation, but this variation was constant and found in almost all subjects (Fig. 5, 6).

The running shoe alone had no significant effect on hip rotation movement in either group of subjects. For this reason, an effect of the cables attached to the legs can also be ruled out.

Due to medial support, the insole ensures that the talus is straightened in the stance phase. The stabilisation of the talus minimised eversion movement. As already explained in the introduction, any movement in the joints can only be a combination of movements. Loading with an upright talus leads to outward rotation of the lower leg. Due to anatomical and muscular conditions, this effect also reduces hip internal rotation.

Both measuring systems showed a gender-specific difference. The reason for a separate analysis of the results was due to already documented differences in previous studies [7]. The results of this study confirm that it makes sense to view each gender separately. However, the results were compared with one another to a limited extent only, as the different drops of the running shoes may have affected the values.

Conclusion and perspective

The insole does not replace specific muscle training to compensate for muscular

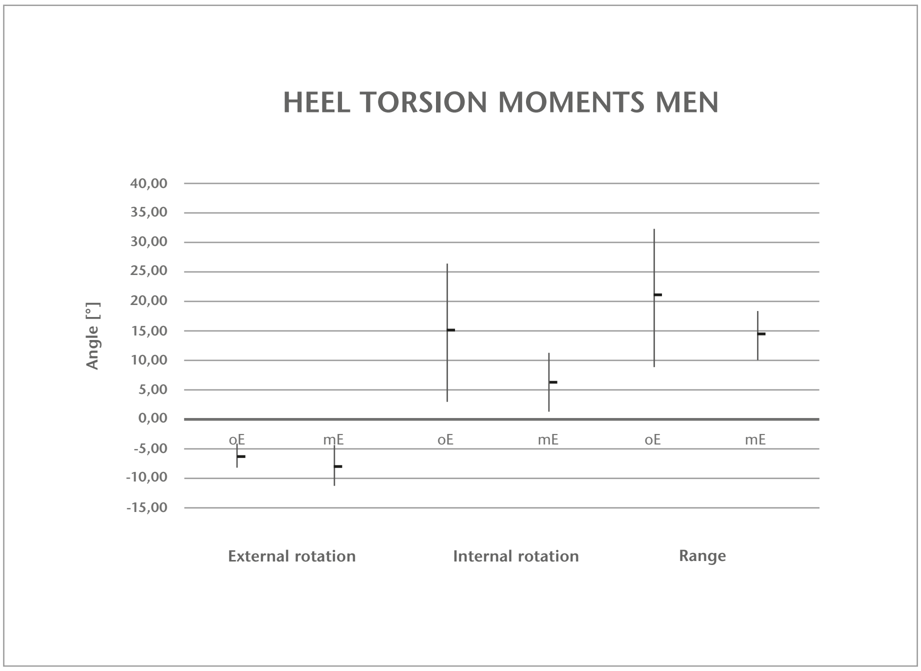

Fig. 7 *Heel torsion moments men.*

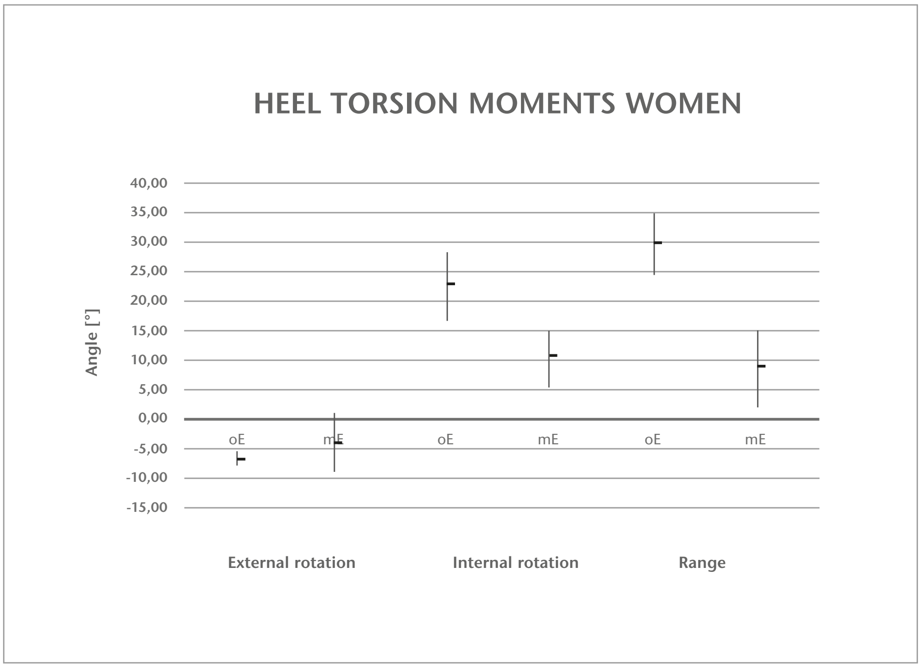

Fig. 8 *Heel torsion moments women.*

imbalance. This training also takes time. However, in running sport especially, there is an interest in at least a temporary quick treatment. A gait analysis and exact observation of movement sequences are therefore absolutely recommended for athletes with one of the syndromes described here. The advantage of the carbon insole is that a small effect can be measured immediately. The carbon insole can optimise the runner's gait, at least with respect to faulty foot loading, ankle movement and hip rotation.

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Reviewed paper

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