Barefoot and in-shoe foot loading changes after fatiguing long distance running
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Introduction: Fatigue fractures are common among long distance runners. They account for approximately 10% of sports overuse injuries (McBryde, 1975) and often affect the foot, especially the metatarsals (Fredericson, 1997, Korpelainen, 2001). The causative factors are not clear yet. Potential reasons for stress fractures can be distinguished between intrinsic factors like age, gender, hormonal factors, low bone density, calcium metabolism, foot structure etc. (Korpelainen 2001) and extrinsic factors like rapid changes in the exercise regime (Lehmann 1987), high weekly training mileage (Korpelainen 2001) or footwear. Mechanical overloading appears to be generally accepted as being potentially detrimental. Especially during fatigued conditions Fatigue causes foot pronation which leads to increased pressure under the medial longitudinal arch due to a modified timing of muscle activity before ground contact (Nigg 2001). Foot loading is routinely assessed in clinical settings with pedobarography in order to identify regions of excessive plantar pressures. This information might also be beneficial for understanding the pathomechanics of metatarsal stress fractures. Therefore, the aim of the present study was to investigate the potential changes of extended running on foot loading characteristics.

Materials and Methods: Twenty-four experienced long-distance runners (age 43.5±8.7 years, BMI 23.4±1.9, weekly mileage 49.3±24.5 km) who were free of injuries or pain at the time of the measurements participated in the study. They were asked to run a distance of 25 km at their individual speed that they considered as appropriate for basic endurance training. On average, they covered the initial 10 km run in 51±5 minutes (3.25 m/s running speed). Heart rate (Polar, Vantaa, Finland) was constantly recorded to assess the level of exertion during and at the end of the run. Step activity was counted with a light-weight accelerometer in order to assess constant running (StepWatch, Cyma Inc., Seattle USA). Pressure measurements (Emed platform, Novel GmbH Munich) during barefoot walking were taken before and after the run. In-shoe pressure measurements (Pedar insoles, Novel GmbH Munich) were recorded on a 200-m indoor track at the beginning of the run, during the run (after 10 km) and at the end of the run (after 25 km). Barefoot and in-shoe foot loading parameters were determined in ten selected foot regions.

Results: A significantly increased heart rate from 146 to 160 bpm (p < 0.0001) indicated that the runners were gradually fatiguing towards the end of the run. However, the SAM data indicated that the cadence remained fairly constant at 56 steps per minute and did not change significantly. Barefoot and in-shoe foot loading parameters after / at the end of the run were significantly reduced under the toes (up to 30%) and significantly increased under the central metatarsal heads (up to 14%).

Discussion: Running under fatigued conditions has the potential to overload foot structures, especially in the metatarsal head regions. These findings support our earlier results during treadmill running at a higher velocity close to the anaerobic threshold (Weist 2004) as well as after a marathon race (Nagel 2007). However, we could not observe previously reported changes in temporal parameters and did not see similar changes in heel loading (Willson & Kernozek, 1999). The observed effects may be due to local muscle fatigue as indicated by the decreased toe function during push-off. The increased forefoot loading and the gradual loss of toe function during push-off might add up to detrimental increase in the metatarsal bending stress (Jacob 2001). This may be a potentially harmful mechanism that could support the development of stress fractures.