ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

Kinetic modifications in running on tilted surfaces

[1] Steffen Willwacher*, [1]Katina Mira Fischer and [1]Gert – Peter Brüggemann
[1]Institute of Biomechanics and Orthopaedics, German Sport University Cologne, Germany
*corresponding author: s.willwacher@dshs-koeln.de

SUMMARY

The purpose of this study was to analyze adaptations in ground reaction force (GRF) and 3D joint moment variables in running on surfaces that differ with respect to their medio – lateral inclination. 19 male subjects were investigated at a constant running speed of 3.5 m/s. Standard inverse dynamics procedures were used to calculate external joint moments. The results indicate that adaptations were strongest at the ankle joint. Further, it could be shown that laterally elevated running surfaces require stronger changes in joint kinetics than medially elevated surfaces. Differences in joint kinetics in the frontal plane of movement might be explained by a systematic shift of the point of force application (PFA) of the GRF and consequent changes in joint moment arms.

INTRODUCTION

Even though running surfaces are rarely perfectly level in typical running environments, only a few studies have analyzed alterations in running biomechanics due to medio – laterally tilted running surfaces. In these studies, adaptations in intra – foot kinematics and ground reaction forces could be identified. [1,2] Nonetheless, changes in joint moments due to medially or laterally tilted surfaces have not been reported yet. Therefore, the purpose of the present study was to analyze kinetic modifications at the joints of the lower extremity. It was hypothesized that changes in joint moments would be strongest in the frontal plane of movement. Further, it was hypothesized that systematic changes in the medio - lateral position of the point of force application (PFA) of the GRF would be found.

METHODS

For the purpose of the study, a custom – made runway was used that can be elevated laterally and medially to inclination levels of 3° and 6°, respectively. Accordingly, four tilted running conditions (med3, med6, lat3 and lat6) were compared to a level running condition (level). 19 male participants (age: 25.6 ± 2.8 years; mass: 76.2 ± 7.4 kg; height: 1.80 ± 0.08 m) ran at a speed of 3.5 m/s over the runway. Marker trajectories of the right leg and pelvis were captured using a ten camera Vicon Nexus (Vicon Motion Systems, Oxford, UK) system operating at 250 Hz. Ground reaction forces were captured using a force platform (2500 Hz, Kistler AG, Winterthur, Switzerland). Massive wooden wedges were screwed on top of the force platform in order to provide an even surface with the rest of the runway. The PFA was calculated in the force platform coordinate system and subsequently transferred to the top of the individual running surfaces. PFA was then expressed in the foot's coordinate system and referenced to the position of the posterior heel marker at the instant of the first contact of the foot with the ground.

External joint moments were used by means of a standard inverse dynamics model. The details of the model are described in a recent publication. [3]

All joint moment and GRF variables were analyzed for the stance phase of the right leg (threshold of vertical GRF: 10 N). A repeated measures ANOVA was used to determine any significant effect of tilt level on the joint moment and GRF parameters in this study. Pair wise t – tests using Sidak's correction of p – levels were used in order to determine differences between conditions, if a significant tilt level effect was detected by the ANOVA. Further, effect sizes (Cohens d) were determined to give an estimate of the relevance of any significant effect.

RESULTS AND DISCUSSION

The strongest adaptations to the tilted runway occurred in the frontal plane of movement. Further, average effect sizes were higher in response to laterally tilted surfaces compared to medially tilted surfaces. The PFA was shifted significantly to the lateral aspect of the foot in the lat3 and lat6 conditions. A significant, but less intense medial shift was observed only for the med6 condition (see figure 1).

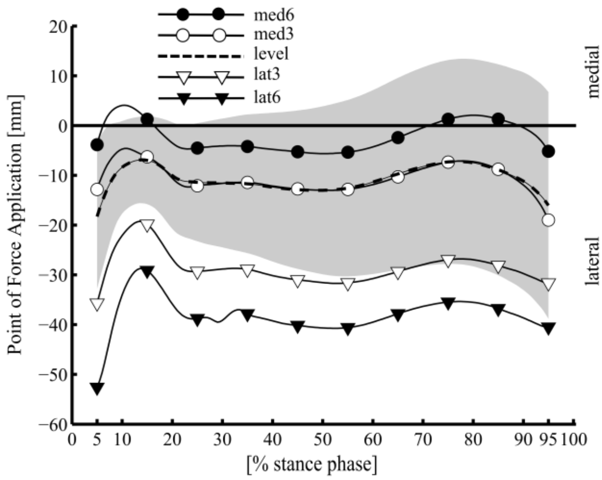

Figure 1: Point of force application in the medio – lateral direction. PFA paths are significantly different for all

analyzed intervals from the level condition with a p – level of at least < 0.01. Gray area represents the mean ± 1 std of the level condition.

On the joint level, the strongest effects were observed at the ankle joint. Here, maximum eversion and internal rotation moments as well as their respective momenta were significantly increased in the lat3 and lat6 conditions (effect sizes between 0.7 and 1.43, see figures 2 and 3). Significant, but opposite effects were also observed for medially elevated conditions, but effects sizes were considerably lower compared to the lat conditions (d = 0.33 – 0.59).

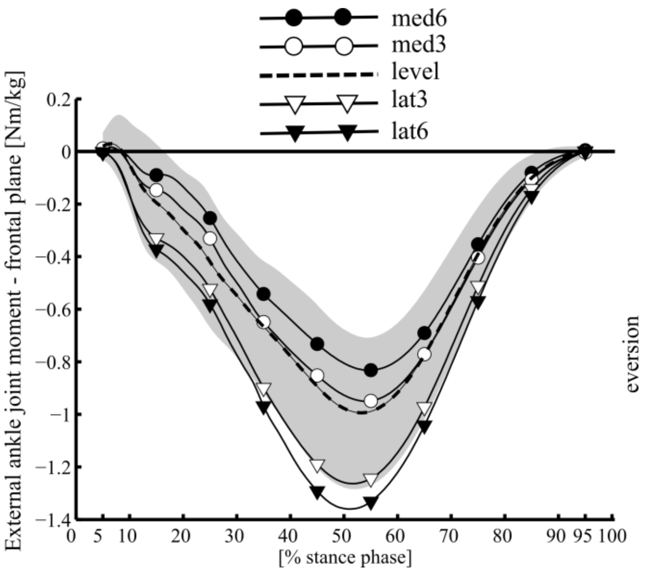

Figure 2: External ankle joint moment in the frontal plane of movement. Gray area represents the mean ± 1 std. of the level condition.

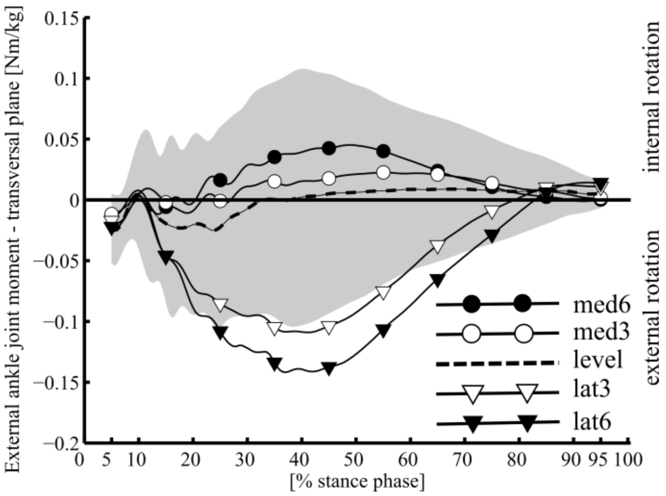

Figure 3: External ankle joint moment in the transversal plane of movement. Gray area represents the mean ± 1 std. of the level condition

At the knee joint, effect sizes were on average lower than at the ankle. A significant decrease in knee flexion and adduction moments were identified for the lat6 conditions (d = 0.22 – 0.38).

At the hip, reduced maximal adduction and internal rotation moments (and momenta) were identified in the med3 and med6 conditions (d = 0.12 – 0.47).

Maximum vertical GRF were significantly lower in the lat6 condition compared to level (d = 0.37).

The results of the present study revealed that alterations of the medio - lateral tilt of the running surface are mainly compensated by kinetic adaptations at the ankle and to a lesser extent at the hip and knee joints. Further, stronger adaptations were needed in running on laterally tilted surfaces compared to medial tilted ones. This might be explained by the higher resistance of the ankle joint complex against eversion movement compared to inversion movement. The observed effects in the frontal plane seem to be well explained by the observed shift of the PFA in the medio – lateral direction and subsequent changes in joint moment arms. Changes in the transversal plane of movement might be due to changes in the footfall pattern of the subjects and should be analyzed in more extensive analysis in the future.

CONCLUSIONS

It could be shown that joint loading and GRF characteristics (especially the PFA) are systematically altered as a function of medio – lateral tilt level of the running surface. Runners that are sensitive to higher joint loading especially of the ankle joint (like during rehabilitation processes) should avoid running on permanently or excessively tilted surfaces. Since typical running injuries most frequently occur at locations distal to the knee joints, [4] the role of the running environment should be further analyzed as a possible contributing factor in future running injury research.

ACKNOWLEDGEMENTS

Parts of this study were funded by a grant of Brooks Sports Inc. (Bothell, WA, USA). The authors are grateful for the help of Martin Küsel - Feldker and Jürgen Geyermann in the construction of the tiltable runway.

REFERENCES

1. Dixon PC, et al., *Gait Posture.* **33(4)**:640-644, 2011.

2. Damavandi M et al. Hum Mov Sci.**31(1)**: 182-189, 2011.

3. Willwacher S et al. *J Appl Biomech..* 2012. ahead of print

4. Ferber R et al. *Sports Health.* **1(3):**242-246, 2009