Lower Limb Biomechanical Analysis of Unanticipated Step on a Bump

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MOTIVATION

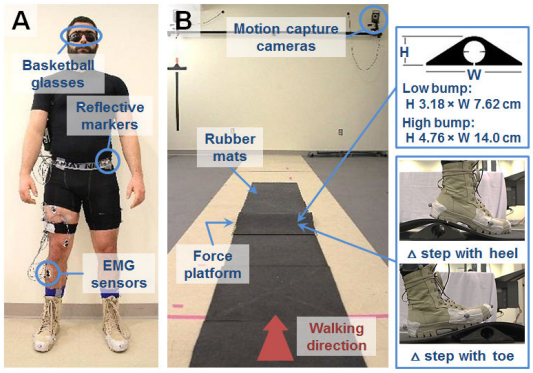
- **Walking on uneven terrains alter the biomechanics of lower limbs** compared to walking on a flat surface [1-3]
- Alterations in overall gait function (slower walking speed, shorter stride length, increased variability) might be caused by alterations at the joint level (higher joint work)and the muscle level (higher muscle activation and co-contraction)
- Nevertheless, it is still not clear **how humans quickly adapt to unexpected variations in terrain while walking**, as most of the previous studies were performed on different surfaces without taking into account sudden changes or irregularity of the surface itself

AIM & HYPOTHESIS

- Aim: **investigate the lower limb joint mechanics when performing an unanticipated step on an irregular surface**
- Hypothesis: the majority of the alterations and changes will happen at the ankle joint as the foot is in direct contact with the ground

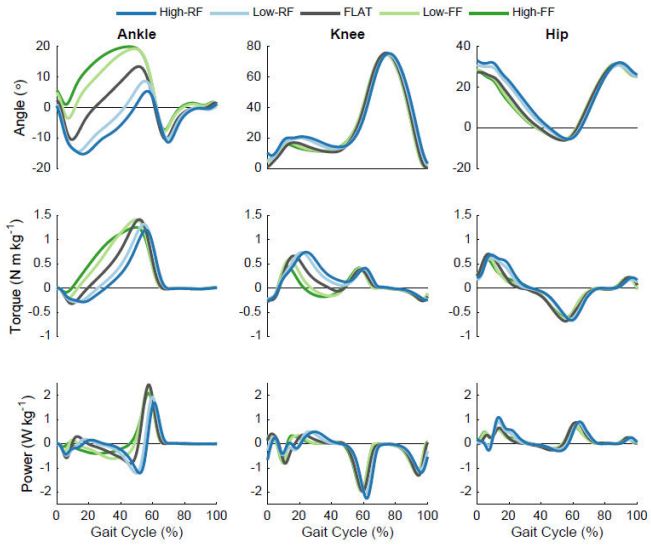
METHODS

- Nine healthy male participants (29.1 ± 4.8 yrs, 76.8 ± 10.2 kg, 176.3 ± 4.7 cm)
- **A baseline condition: walking along a straight walkway at preferred speed (*FLAT*)**
- **Four conditions with bump: stepping on two different size bumps with right forefoot (*High-FF*, *Low-FF*) or right rearfoot (*High-RF*, *Low-RF*) while walking**
- Measurements: 3-D motion capture using 41 markers, ground reaction forces and moments using a force plate, electromyography (EMG) of 8 lower-limb muscles



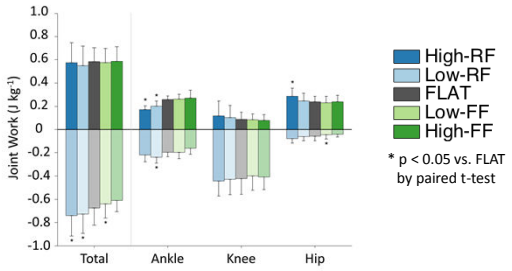
RESULTS

Joint kinematics and kinetics

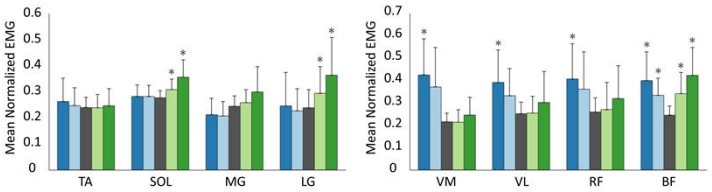


RESULTS (contd.)

Joint work



EMG



DISCUSSION

Toe conditions

- **Higher dorsiflexion and plantarflexion moment production**, confirmed by higher EMG activation in the SOL and the LG muscles
- The ankle is more dorsiflexed so there is an increased stretch of the plantarflexor muscles at the heel strike
  → The ankle joint exploits the catapult mechanism of muscle-tendon complex
  → Lower moment at knee and hip, higher ROM at hip, higher BF activation
- **A higher co-contraction at the thigh indicates an instability of the more proximal joint** which might try to compensate the perturbation introduced at the ankle level

Heel conditions

- Conversely, **less dorsiflexion angle** and **less moment and less work production**
- The ankle is more plantarflexed at the heel strike and the duration of the plantarflexion moment production is reduced
  → This reduces the normal stretching-shortening cycle of muscle-tendon complex
  → The reduced moment produced by the ankle is compensated by the other joints
  e.g. The knee produces a higher moment and the hip produces more power
- There is **a higher co-contraction both at the thigh and at the ankle**

Comparison with other work

- Some of the adaptations found in the present study were reported also by previous studies investigating walking on uneven terrain [1-3]
- Nevertheless, we **specifically investigated rearfoot and forefoot conditions**
  → Further **explored specific adaptations that might have been previously undistinguished** by studies investigating general adaptations to uneven terrain
- **Increase muscle activation and increased co-contraction are generally a sign of instability** and are associated with walking on uneven terrains
  → Reflects a higher metabolic cost associated with walking over uneven terrains

Conclusion

- These findings provide **insights to how humans quickly react to unexpected events and explore the specific effect of different perturbations**
- Future work: **develop controllers for assistive devices**, e.g. soft exosuit [4-6], **which can adapt to different terrains**

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