COMPARISON OF STIFFNESS AND MAXIMAL FORCE IN OVER GROUND AND TREADMILL RUNNING AND HOPPING

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Introduction

During each step of running and hopping the knee undergoes a substantial flexion during the first half of stance and extension during the second half of stance. The stiffness of the leg is controlled by muscular activity when running [McMahon, 1985] and hopping [Blickhan, 1989]. The aim of this study was to compare the mechanical difference of maximal vertical force, stiffness and muscle activity when running and hopping at the same velocity over ground (OG) or on a treadmill (TM).

Methods

Ten experienced healthy male runners (age, 36.5±13.2 years; mass, 68.1±4.5 kg; height, 174.5±4.6 cm) participated in the experiment. They had to run and hop OG at self-selected velocity, before running/hopping at the same velocity on the TM (hop: also same frequency).

We measured body segment kinematics (Vicon Plug-in-Gait) and surface EMG of both upper legs of rectus femoris (RF), vastus medialis/lateralis (VM/VL) and biceps femoris (BF).

The COM velocity was numerically differentiated to get the acceleration in vertical direction. Based on the acceleration and subjects' mass the vertical force was determined. For each step we selected the maximal vertical force and determined the stiffness $k=\Delta Fv/\Delta h$ (ΔFv: change in vertical force during stance; Δh: change in vertical height during stance).

The surface EMG was processed to get the EMG amplitude for each muscle [cf. Staudenmann, 2007], which was averaged between legs. The degree of co-contraction was determined as the ratio between anterior and posterior EMG amplitude of the upper leg muscles.

Results

The maximal vertical force showed no significant difference between OG and TM locomotion (run 1591±202N; hop 2854±442N; p=0.254). Stiffness showed a significant increase of 6% for TM running (21.8±3.4kN/m, 23.1±3.2kN/m; p=0.015), and a non-significant increase of 6% for TM hopping (19.3±5.3kN/m; p=0.324). Δh was 7.1±0.7cm for running and 15.2±1.7cm for hopping. Co-contraction was 9% higher for TM running and reduced by -41% for TM hopping, both were statistically non-significant (p>0.074).

Discussion

The maximal vertical force showed no significant difference between OG and TM for running and hopping, whereas the stiffness of TM running was increased. This can be related to the larger co-contraction of the upper leg muscles [cf. McMahon, 1990] on the TM.

Hopping showed a 16% lower stiffness then running. This difference is related to the maximal vertical force found to be 80% larger for hopping than for running, and to the change in knee flexion during contact (Δh) that was about twice as large for hopping [cf. Blickhan, 1989]. Furthermore, we have to take into account that the contact of hopping is generated by two legs instead of one leg in running. Calculated over one leg, the hopping maximal vertical force and stiffness with one leg were found to be much lower than in running (10% and 57%, respectively).

It can be concluded that the stiffness is significantly increased for running on the TM but not for hopping. The difference may be explained because the athletes were used to run but not to hop OG and on the TM. Therefore, large inter-subject variability may be responsible for non-systematic effects during hopping. Interestingly, co-contraction of upper leg muscles was non-systematically increased by 9% for TM running and decreased by -41% for TM hopping as compared to OG.

References

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