3D JOINT CONTACT FORCES AT THE HIP, KNEE, AND ANKLE DURING RUNNING AT DIFFERENT STRIDE LENGTHS

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INTRODUCTION

Repetitive mechanical loading has been associated with lower limb joint pain (Radin et al., 1991). The joint contact forces that arise from mechanical loading are due to a combination of reaction forces and muscle forces. During running, ground reaction forces can be reduced by shortening stride length (Mercer et al., 2005). It is unclear if shortening stride length has similar effects on joint contact forces.

The purpose of this study was to determine if reducing stride length decreased joint contact forces and joint contact loading rates during running.

METHODS

Five experienced male runners participated in this study (age: 21.6 ± 3.3 yrs, height: 176.5 ± 2.9 cm, mass: 68.5 ± 4.6 kg). Kinematic and kinetic data were collected while subjects ran at their preferred stride length (PSL) and -10% their preferred stride length (-10%PSL). Subjects performed ten trials at each condition. Stride length was adjusted by having the subjects strike targets placed on the floor. A trial was considered successful if the subject consistently hit the targets and was within ± 5% their preferred running velocity. The average preferred running velocity was 4.2 ± 0.3 m/s.

Three dimensional kinematics of the thigh, leg, and foot were calculated using a flex/ext, abd/add, introt/extrot sequence. Inverse dynamics was used to obtain three dimensional joint reaction forces and joint moments at the hip, knee, and ankle. Muscle forces for 45 lower extremity muscles were then calculated using computer optimization.

The kinematic data were imported into a scaled SIMM 4.0 model to obtain maximal dynamic muscle forces, muscle moment arms, and muscle orientations at each 1% of stance. This information was then exported into Matlab 7.0.4 to calculate muscle forces using the *fmincon* optimization routine. The cost function to be minimized was the sum of cubed muscle stresses. The optimization was constrained so that the resulting hip, knee, and ankle moments equaled experimental data. Six moments were used in the optimization including: Hip flex/ext, abd/add, introt/extort; Knee flex/ext; Ankle flex/ext, inver/ever. The lower and upper bound muscle forces were originally set to zero and the maximal dynamic muscle forces respectively. These bounds were then adjusted in subsequent frames to prevent non-physiological changes in muscle force (Pierrynowski & Morrison, 1985).

Joint contact forces were calculated in the distal segment reference frame as the sum of reaction force and muscle forces crossing the joint. Peak instantaneous forces and loading rates were then calculated for the hip, knee and ankle joint in the axial and shear directions (anterior-posterior, or AP; medial-lateral, or ML). Peak forces and loading rates were averaged across trials for each subject and effect sizes between conditions were calculated. We used Cohen's (1992) suggestion that effect sizes of .20 are small, .50 are medium, and .80 are large. Only variables with medium effect sizes, or better, are reported below.

RESULTS AND DISCUSSION

Axial joint contact forces were similar to those previously reported for running (Glitsch & Baumann, 1997). While axial forces were always compressive, the direction of AP and ML shear forces were dependent upon the joint and percentage of stance (Figure 1). Peak axial loading rates always occurred during the impact phase of stance between 0 and 30%. The occurrence of peak shear loading rate varied.

Medium effects were observed for ML hip force (-0.64), ML ankle force (-0.56), and ML ankle loading rate (-0.61). Large effects were observed for axial hip loading rate (-1.07), ML hip loading rate (-1.33), and axial knee loading rate (-0.82). For each variable the effect size was negative indicating a lower value during -10%PSL.

SUMMARY/CONCLUSIONS

These findings suggest that decreasing stride length may be an effective way to minimize repetitive mechanical loading that occurs during running. Future research will look to increase sample size to see if these trends are statistically significant.

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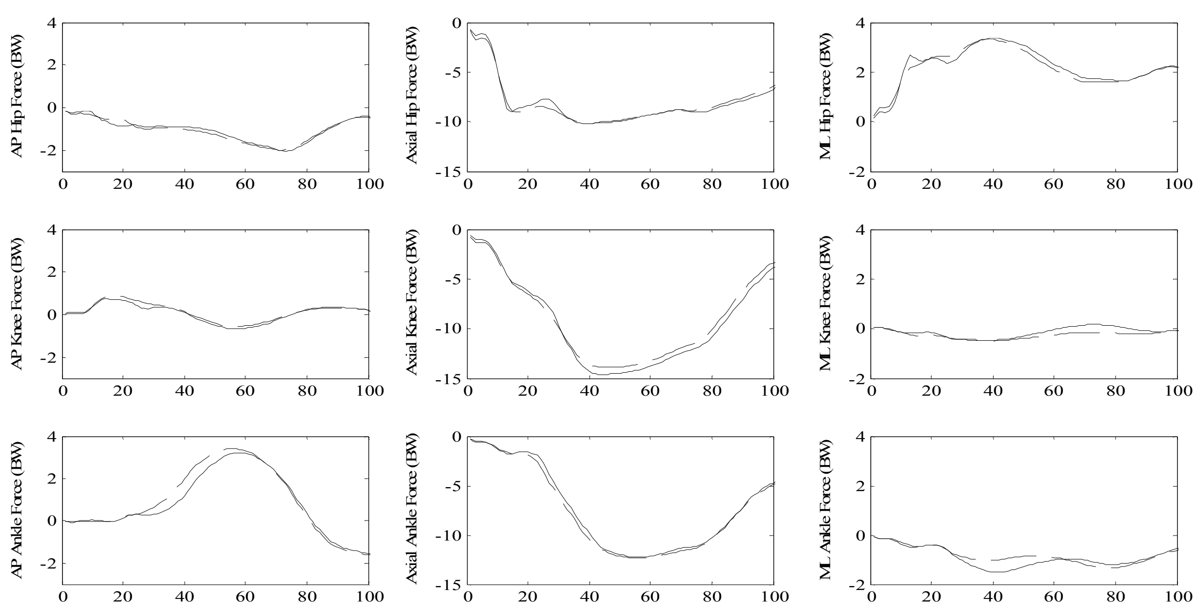

Figure 1: Ensemble average axial and shear joint contact forces at the hip, knee, and ankle for one subject. Solid line = PSL; Dashed line = -10%PSL; +AP = anterior shear; +Axial = tension; +ML = lateral shear.