KNEE JOINT MOMENTS DURING SINGLE-LEG FORWARD HOPPING

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INTRODUCTION

Hopping is not often performed by healthy adults, but is common in amputees when not wearing their prosthetic leg, and in individuals who have their leg in a cast. Many physicians advise against hopping for ambulation in lower-extremity amputees, but recognize that in some situations it is unavoidable, for example, when maneuvering around the home before being fitted for a prosthesis [1], or simply when wearing the prosthesis is not convenient.

The prevalence of knee osteoarthritis (OA) in the intact limb of lower-extremity amputees is nearly twice that of non-amputees [2]. Increased loading of the intact limb is thought to be a contributing factor to the higher rate of OA in amputees compared to non-amputees [2]. However, to our knowledge there have been no studies investigating knee joint loading during single-leg forward hopping, in any population. Therefore, assessing the loads on the knee joint during single-leg forward hopping would enable us to make recommendations on whether frequent single-leg hopping is safe and healthy for the knees.

The purpose of this study was to compare the knee joint mechanics, specifically frontal and sagittal plane joint moments, of healthy adults during walking, running, and single-leg forward hopping. We hypothesized that knee joint moments would be greater in hopping than in walking or running.

METHODS

Six healthy adults (2 males, 4 females) participated after giving written informed consent. Participants completed three different locomotion conditions: running for three minutes at 3.0 m/s and walking for five minutes at 1.0 m/s around a 50-m indoor track, and three trials of hopping forward on one leg across a 12-m platform at 2.0 m/s. The target speeds were chosen because they were close to self-selected speeds in pilot testing.

Kinematic data were captured using a 12-camera Vicon motion capture system, and force data were captured using eight Kistler force plates embedded in the platform. Knee joint moments were calculated by inverse dynamics using Visual3D. A one-way repeated measures ANOVA (p < 0.05) tested for the effect of locomotion condition on the external knee adduction moment’s (KAM) peak, impulse, and loading rate (LR), and the peak knee flexor moment (KFM). These variables were selected due to their prior association with OA [3-5]. Post-hoc testing was performed using Tukey’s LSD.

RESULTS AND DISCUSSION

Average performed speeds for each condition were: hopping (1.93±0.11 m/s), running (2.87±0.05 m/s), and walking (0.99±0.08 m/s). Average stride lengths were: hopping (0.88±0.25 m), running (1.80±0.30 m), and walking (1.01±0.30 m). The mean values of joint moment time series for all locomotion conditions are presented in Figure 1.

The ANOVA revealed a main effect for locomotion condition on all outcome variables, with several significant post-hoc differences, all with p < 0.01:

For KAM impulse
- Between hopping and running (0.92±0.31 vs. 0.54±0.18 %BW*Ht*s)

For peak KAM
- Between hopping and running (4.44±2.06 vs. 2.48±0.89 %BW*Ht)
- Between hopping and walking (4.44±2.06 vs. 2.57±0.39 %BW*Ht)

For peak KFM
- Between hopping and running (20.02±3.99 vs. 17.2±2.96 %BW*Ht)
between hopping and walking (20.0±3.99 vs. 3.98±1.26 %BW*Ht)
- Between running and walking (17.2±2.96 vs. 3.98±1.26 %BW*Ht)

For KAM LR
- Between hopping and walking (0.52±0.14 vs. 0.25±0.04 BW*Ht/s)
- Between running and walking (0.40±0.05 vs. 0.25±0.04 BW*Ht/s)

Hopping therefore increased the assessed features of the knee joint moments (peaks of KFM and KAM, impulse of KAM, and KAM LR) compared to walking and/or running. Peak KFM, peak KAM, and KAM impulse have been previously associated with the longitudinal initiation and/or progression of knee OA [3,4], and KAM LR has been associated cross-sectionally with poorer tibiofemoral cartilage health scores [5]. These differences in moments would presumably be manifested internally as increased or otherwise abnormal mechanical loading of the articulating tibiofemoral surfaces. In particular, the rapid horizontal starting and stopping motion of hopping likely places high shear forces on the knee, especially if the compressive loading presumably reflected by these joint moments is also high.

The relatively high risk of OA in intact limb of amputees is thought to result from increased loading due to overreliance on this limb in performing activities of daily living. Therefore, hopping as a form of ambulation may contribute to the development of knee osteoarthritis by placing loads on the cartilage that it is not accustomed to sustaining, and warrants further investigation in the amputee population.

CONCLUSIONS

Single-leg hopping is often performed by lower-extremity amputees when ambulating without a prosthesis. However, hopping places large loads on the knee joint, and increased knee joint loading may be a contributing factor in the development or progression of knee OA. Therefore, it may be advisable to limit single-leg hopping as a form of locomotion in amputees.

REFERENCES