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The effect of lower-body positive-pressure treadmill training in early rehabilitation for patients with lower extremity fractures

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Introduction

Early mobilization and rehabilitation is emphasized to patients with multiple musculoskeletal injuries by trauma but gait training for people with pelvic or multiple lower extremity fracture is limited in acute rehabilitation stage by pain, weight bear restriction or other soft tissue injuries. Lower-Body Positive-Pressure treadmill (LBPPT) loads off the weight to the lower extremity by applying air chamber to lower extremity and the gait training with less weight bear to the injured leg is feasible. Only a few previous studies reported the benefit of LBPPT for patients with knee osteoarthritis.

Research Question

To assess the safety and effect of anti-gravity gait training using LBPPT for patients with pelvis or multiple lower extremity fractures in sub-acute stage of rehabilitation.

Methods

Prospective interventional study from an acute inpatient rehabilitation hospital. Participants underwent gait training in anti-gravity environment using LBPPT for twenty-five minutes (5 minutes' warm up, 15 minutes' walking in comfortable speed, 5 minutes' cool down), total of twenty sessions (5 times a week for 4 weeks). The target walking speed was 2mph and un-weighting was set as individuals' weight bearing restriction percentage. For participants without weight bearing restriction, anti-gravity percentage was gradually increased to the target speed 2mph without discomfort nor significant gait abnormality noted. Joint specific disability and osteoarthritis outcome score (Hip: HOOS, Knee: KOOS, Foot & Ankle: FAOS) was measured at baseline and at the completion of 4weeks of gait training. Gait patio-temporal parameters using Motion Analysis®, 10meter walk test, time up-and-go, and manual muscle test of both leg were measured as well. X-rays of the fracture site were taken to screen any adverse effect on bone union.

Results

Seventeen individuals (mean age 34.5 ± 15 years) with more than one fracture of lower extremity including pelvis, completed the study and reached 2mph gait speed goal during the anti-gravity treadmill training. After 20 session of training, the joint specific disability and osteoarthritis outcome total score has improved ($p < 0.001$), especially in pain, symptoms and quality of life. Improved gait speed ($p < 0.001$) and length ($p < 0.001$), and time up-and-go ($p = 0.01$) were observed. No adverse event nor mal-union of the fracture site on radiography was observed.

Discussion

This is experimental study to assess benefit and safety of LBPPT gait training in subacute rehabilitation stage for patients with gait disturbance due to lower extremity fracture. Randomized control study should be followed to compare the effect in clinical and gait parameters of LBPPT over the conventional off-weight bear rehabilitation

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The shape and size of the femur adapts during growth to maintain a constant cartilage load

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Introduction

Joint loads depend on a person's musculoskeletal geometry [1], walking pattern [2] and muscle coordination [3]. In typically developing (TD) children the bony geometry [4,5], and walking pattern [6,7] might change over time, and consequently affect joint loads and cartilage pressure. Getting a better understanding about the relationship between bony morphology and internal joint loads in TD children is crucial for understanding typical and pathological growth [8,9].

Research Question

How does growth-related changes in femoral morphology affect hip joint loads?

Methods

Magnetic resonance images (MRI) of the femur and 3D motion capture data were collected from 10 TD children on two occasions, approximately 2 years apart (age: first session 9.9 ± 0.9 years). For each participant and data collection session, the femoral anteversion (AVA) and neck-shaft angle (NSA) were calculated based on information from the MRIs [10]. Personalized musculoskeletal models were created for each data collection session [11–13] and used to calculate joint angles, muscle forces and joint contact forces (JCF) using OpenSim [14]. Hip joint contact surface was estimated as 40% of a sphere fitted to the femoral head surface [15,16], obtained from the MRI images. Hip joint cartilage pressure was estimated by dividing the hip JCF with the hip joint contact area. Additional fictive simulations based on the motion capture data of the second session but a musculoskeletal model with the femoral geometry from the first MRI session were performed, which enabled us to quantify alterations in JCF and cartilage pressure solely caused by the growth-related changes in femoral morphology. Statistical parametric mapping [17] was used to compare joint angles, JCF and cartilage pressure between both data collection session and different simulations. Multiple regression analyses were used to investigate if changes in AVA and hip joint contact area had a significant impact on JCF and cartilage pressure.

Results

Height and weight significantly increased ($p < 0.001$) from session 1 to session 2. AVA significantly decreased ($p = 0.003$) from 33 ± 8° to 29 ± 8°, whereas NSA remained constant (129 ± 4° and 128 ± 4°, $p = 0.613$) during the two-year period. Walking speed and joint kinematics were similar between sessions with no significant differences. Absolut hip JCF significantly increased but JCF normalized to body weight did not differ between sessions. Regression analysis revealed a significant relationship between the reduction in AVA and decrease in hip JCF ($R = 0.82$, $p < 0.001$). Changes in hip joint cartilage pressure were significantly correlated ($R = 0.86$, $p < 0.001$) with changes in AVA ($p = 0.03$) and changes in hip joint contact area ($p < 0.001$).

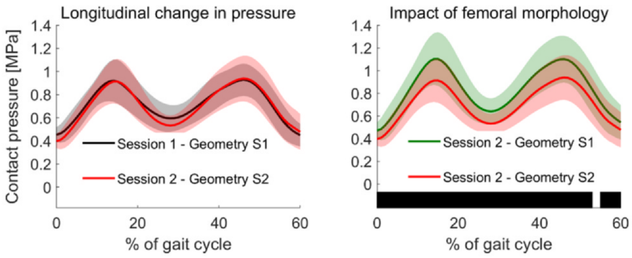

Fig. 1. Hip joint cartilage pressure from session 1 and 2. Green waveforms are from the fictive simulations. Black bar indicates significant differences based on the SPM analysis.

Discussion

Our findings highlight that growth-related alterations in femoral morphology decrease hip loads. Consequently, it appears that the adaptation of femoral morphology, especially the increase in femoral head surface, serves as a mechanism to maintain hip cartilage loads within healthy limits, despite the increase in body weight.

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Morphometric analysis of growth-related changes in femoral geometry

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Introduction

Torsional deformities of the femur, common in patients with and without neurological disorders [1,2], can lead to altered gait, increased risk of falls, joint pain, overuse injuries and osteoarthritis [3–6]. Understanding typical growth pattern is essential for clinical assessment of pathological femoral growth [7,8]. So far, most longitudinal evaluations of femoral growth were based on simplified geometrical measures, e.g., anteversion and neck-shaft angle, based on a few ($n < 6$) anatomical landmarks [3,9].

Research Question

Does femoral shape change with size during ontogeny?
Is femoral torsion affected by ontogenetic growth?

Methods

Magnetic resonance images (MRI) of the femur were collected from 10 typically developing children on two occasions, approximately two years apart (age: first session 9.9 ± 0.9 years). For each participant and data collection session, the femoral anteversion (AVA) and neck-shaft angle (NSA) were calculated based on clinical measures from the MRIs [10]. MRIs were segmented using 3Dslicer [11]. On each femur 121 evenly distributed landmarks and semi-landmarks (Fig. 1) were defined and used for geometric morphometric analyses. We used Generalized Procrustes Analyses to obtain centroid size and shape variables [12]. We addressed the research questions using principal components analysis in shape, and form space and regression analyses of shape on size.

Results

During the two-year period, clinical measures showed changes in femoral anteversion and neck-shaft angle from 35 ± 9° to 33 ± 10° and 127 ± 4° to 130 ± 4°, respectively. Morphometric analyses revealed a significant relationship between shape and size. A linear model of multivariate regressions explains 12.8% of shape variance ($p = 0.005$) with 1000 permutations. Size differences were highly statistically significant (S1: 1465.5 mm; S2: 1612.2 mm, $p < 0.001$). Shape variation was not very strongly organized by ontogenetic size changes, indicating high inter-individual variation between femurs. Main shape changes (Fig. 1) within the two years included: decrease in the relative anterior-posterior dimension of the lateral condyle and a more curved femoral shaft. Modification of the orientation of the head-neck complex led to a decrease in femoral torsion.

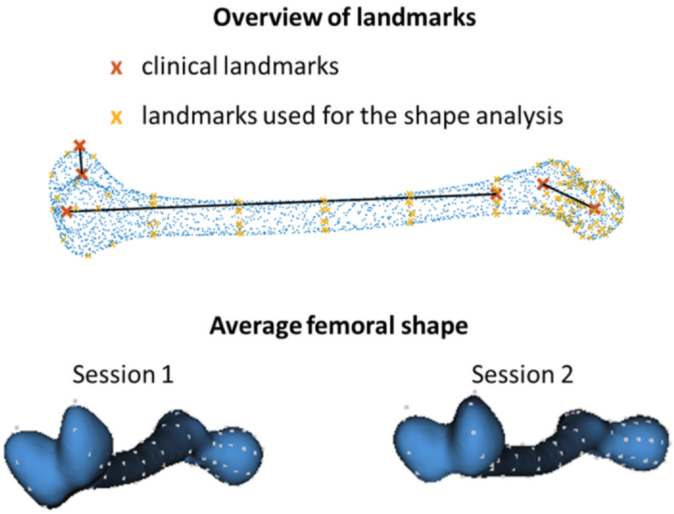

Fig. 1. Overview of landmarks (top subplot) and average femoral shape from the morphometric analysis (bottom subplot).

Discussion

Our results showed that femoral torsion is not simply a mechanical rotation of proximal and distal femur elements along the axis of the shaft, but a complex morphological result of different growth modifications. A recent study [13] showed that some children with cerebral palsy have more bending in the femoral shaft compared to healthy children. Considering that we showed that the shaft curves during growth, the more curved femur in children with cerebral palsy might be caused by modified ontogenetic change of the femur, potentially caused by differences in the biomechanical loading