PATIENTS AFTER PEMBERTON’S OSTEOTOMY FOR DEVELOPMENTAL DYSPLASIA OF THE HIP WALKED WITH AN ASYMMETRICAL GAIT PATTERN WITH GREATER JOINT LOADING IN AFFECTED AND UNAFFECTED LIMBS

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SUMMARY
This study aimed to investigate how the affected and unaffected limb in patients after Pemberton’s osteotomy for unilateral DDH interacted mechanically for the increased joint loading around heelstrike in both limbs. At similar gait speed, the Pemberton group walked with asymmetrical gait patterns which were also significantly different from those of the healthy controls. These residual gait deviations may contribute to the significantly greater rates of repetitive loading around heelstrike in both affected and unaffected hips.

INTRODUCTION
Developmental dysplasia of the hip (DDH) is characterized by a displaced femoral head at a formed acetabulum with insufficient coverage that would lead to greater joint contact pressures and eventually joint osteoarthritis (OA). Therefore, early treatment is necessary. Pemberton’s osteotomy is among the most frequently performed procedures for treating DDH. While correction of DDH may improve the function of the hip, insufficient congruency may still result in uneven stress distribution on the articular surfaces [1], which may further lead to high incidence of avascular necrosis (AVN)[2] and acetabular dysplasia.[3, 4] A recent study also showed that greater rates of repetitive loading around heelstrike in both hips in these patients may be at a higher risk of premature hip OA, especially when incomplete coverage, insufficient congruency and/or damaged articular surfaces remained after the Pemberton’s osteotomy for unilateral DDH [5]. This study aimed to investigate the mechanical interactions between the affected and unaffected limbs in patients after Pemberton’s osteotomy for unilateral DDH, which led to the increased rates of repetitive loading around heelstrike in both hips.

METHODS
Eleven adolescent females treated for unilateral DDH by Pemberton’s osteotomy (age: 10.55±0.98 years, height: 140.82±7.98 cm, body weight (BW): 33.59±8.30 kg) and twelve healthy adolescent females (age: 10.99 ± 1.48 years, height: 143.17 ± 9.36 cm, BW: 35.34 ± 7.45 kg) participated with informed written consent. Each subject walked at a self-selected pace while the kinematic and ground reaction force (GRF) data were measured using a Vicon 512 system and 2 AMTI forceplates, respectively. The peaks and the values of the joint angles and moments at the beginning and end of single leg stance (bSLS and eSLS), and the peak GRF were extracted. Gait speed, cadence, stride length and the vertical acceleration of the heel marker at the end of the swing phase were also calculated. The non-parametric Mann-Whitney U test and the Wilcoxon signed ranks test were used to detect the differences between the two groups and between the affected and unaffected side in the Pemberton group, respectively. All significance levels were set at α=0.05.

RESULTS AND DISCUSSION
The means of gait speed, cadence and stride length were not statistically different between the two groups and between the two limbs in the Pemberton group (Table 1). This is in contrast to the significantly slow walking in the untreated patients,[6, 7] which indicated that the current Pemberton group walked more efficiently than the untreated patients did. Compared to the control group and the contralateral limb, the affected limb of the Pemberton group had significantly greater peak knee flexion during the swing phase and kept similar to normal knee flexion at the next heel-strike (Figure 1), which implied a rapid increase in the knee extension of the affected limb during the late swing with increased GRF at the next heel-strike. Significantly decreased upward acceleration of the heel marker (Table 1) also indicated the decrease in the braking effort of the affected limb at the heel-strike (Figure 2). Such greater knee flexion and decreased braking force of the GRF would lead to significant decreases in the hip extensor and knee flexor moments at heel-strike (Figure 3).

The knee joint in the unaffected limb of the Pemberton group had similar kinematic pattern during the swing phase and at heel-strike when compared to the controls (Figure 1). Corresponding to the moment when the unaffected limb struck the ground, the affected limb displayed greater knee and ankle flexion during the terminal double limb support. The affected limb also transferred its weight to the unaffected limb at the eSLS with greater anterior propulsive force. Therefore, the unaffected limb demonstrated greater vertical and posterior GRF (Figure 2), greater ankle plantarflexor and hip extensor moments and smaller knee extensor moment (Figure 3).

CONCLUSIONS
The Pemberton group walked with similar speeds but displayed significantly different kinematic and kinetic patterns when compared to the healthy controls. Asymmetrical gait patterns were also found in the Pemberton group. These residual gait deviations may lead to increased joint loading in
both limbs and loading rates in both hips around heelstrike as reported in Chang et al. [5]

ACKNOWLEDGEMENTS
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REFERENCES

Table 1 Means and standard deviations of the temporo-spatial parameters in the Pemberton and the control groups.

<table>
<thead>
<tr>
<th></th>
<th>Pemberton group</th>
<th>Control group</th>
<th>Comparisons between two groups</th>
<th>Comparisons between two limbs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Affected</td>
<td>Unaffected</td>
<td></td>
<td></td>
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<tr>
<td>Gait speed (m/s)</td>
<td>1.08 ± 0.13</td>
<td>1.14 ± 0.16</td>
<td>0.234</td>
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</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>112.68 ± 11.53</td>
<td>119.01 ± 10.90</td>
<td>0.126</td>
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<tr>
<td>Vertical accelerations of the heel at the end of the swing phase (mm/s²)</td>
<td>9742.1 ± 4691.8</td>
<td>6604.1 ± 4736.8</td>
<td>0.036</td>
<td>&lt;0.001</td>
</tr>
</tbody>
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Figure 1: Averaged knee flexion in the affected (black, solid line) and unaffected limb (black, dotted line) of the Pemberton group and in both limbs of the normal group (gray, solid line).

Figure 2: Averaged anterior-posterior and vertical GRF in the affected (black, solid line) and unaffected limb (black, dotted line) of the Pemberton group and in both limbs of the normal group (gray, solid line).

Figure 3: Averaged joint moments at the hip, knee and ankle joints in the affected (black, solid line) and unaffected limb (black, dotted line) of the Pemberton group and in both limbs of the normal group (gray, solid line).