INTRODUCTION:
Cam femoroacetabular impingement (FAI), the result of abutment between an aspherical proximal femur and the acetabular rim during hip movement, is a well documented source of hip pain in young active adults1 which may progress into hip osteoarthritis2. Most often, symptoms of FAI arise during movements that solicit the extremes of range of motion (ROM) of the hip, but have also been reported during activities requiring normal ROM of the hip as seen during walking3. Surgery to correct cam FAI has become the popular treatment option. Despite this, no known study has used motion analysis and ground reaction forces to quantify the outcome after surgery for cam FAI using an open or combined approach. The purpose of this study was to determine the effects of cam FAI corrective surgery on the kinematics and kinetics of the affected hip during level walking. We hypothesized that the hip mechanics of FAI patients during level walking would resemble more those of healthy control subjects, after surgery.

METHODS:
Ten cam FAI patients were compared preoperatively and postoperatively, and with thirteen control subjects matched for age, sex and body mass index. All patients were operated by the same surgeon using an open or combined approach. Depending on the surgical approach utilized, some hip joint muscles were incised or detached to allow greater exposure of the impingement site. Postoperative testing occurred between eight and thirty-two months after surgery. Prior to their involvement in the study, each participant provided their informed written consent, which was approved by the Research Ethics Board.

Three-dimensional (3-D) kinematics and kinetics of the lower-extremity joints were measured during level walking using a nine-camera motion analysis system (Vicon MX, Oxford Metrics, UK). Participants were outfitted with forty-five retro-reflective markers, placed according to a modified Helen Hayes model4. Ground reaction forces were recorded during the stance phase of the gait cycle using a force platform (Model FP4060-08, Bertec Corp., Columbus, OH, USA). Participants performed five walking trials at a natural, self-selected pace. The kinematic variables of interest were the peak angles and ROM of the hip in all three planes during the gait cycle. Furthermore, peak hip moments in all three planes and peak hip powers were obtained for the stance phase of the gait cycle. The variables acquired for the affected leg during the five walking trials were averaged for each preoperative and postoperative cam FAI patient. For each control subject, the variables obtained from both legs during the five walking trials were averaged.

A series of multivariate analyses of variance (MANOVAs) were conducted to compare the preoperative and postoperative cam FAI groups with the control group. Also, multiple repeated-measures MANOVAs were used to detect statistically significant differences between the preoperative and postoperative cam FAI groups. Since many comparisons were made in each plane, the alpha values were adjusted to α = 0.017 for all kinematic variables and to α = 0.025 for all kinetic variables.

RESULTS:
The hip kinematic and kinetic variables found to be statistically significantly different between the control, preoperative FAI and postoperative FAI groups during level walking are shown in Table 1. Results revealed that the hip frontal plane ROM of FAI patients during level gait remained unchanged following surgery. As a result, both preoperative and postoperative FAI groups exhibited a significantly smaller hip frontal plane ROM, by 3.5°, compared to the control group. Conversely, the postoperative hip sagittal plane ROM diminished by 0.6° compared to the preoperative values, which was enough to convert the statistical trend found between preoperative FAI and control groups to a statistically significant reduction of 4.7° for the postoperative FAI group compared to the control group. Moreover, the preoperative FAI group produced smaller peak hip abduction and external rotation moments compared to the control group. However, these differences were not statistically significant. The postoperative FAI group produced even smaller peak hip abduction and external rotation moments than that preoperatively, differing significantly from that of the control group.

DISCUSSION:
The primary objective of this study was to examine the effects of cam FAI corrective surgery on the kinematics and kinetics of the affected hip of FAI patients during level walking at a self-selected pace. Contrary to our hypotheses, it was determined that the gait mechanics of FAI patients did not return to normal following surgery.

Both peak hip abduction and external rotation moments occurred near the time of transfer from double-limb stance to single-limb stance onto the affected limb. It has been proposed that, at this time, hip surgery patients adopted a pelvic stabilization technique, reducing their hip motion in the frontal plane, allowing them to produce a smaller hip abduction moment – and perhaps a smaller hip external rotation moment – to counteract an opposing moment produced by their centre of mass5. As underlined by Beaulé et al. (2010), it is possible that preoperative hip surgery patients (e.g. preoperative FAI patients) adopted modified gait patterns to reduce hip muscle contractions, loading and pain, resulting in muscular disuse and atrophy. This theory could explain the slight kinetic and kinematic differences observed between preoperative FAI patients and healthy control subjects. Moreover, the postoperative discrepancies in hip mechanics may have been caused by the surgery. Of interest, similar frontal plane gait pattern alterations have been noted in patients having undergone total hip arthroplasty – a surgical technique which closely resembles that used to treat FAI patients – and have been proposed to result from weakened hip abductors, postoperatively6. In the present study, ten cam FAI patients were operated using either an open or combined approach. The open technique required incision of the iliobial band and splitting of the gluteus maximus; while the combined technique occasionally necessitated the release of the reflected head of the rectus femoris. Seeing as these muscles are major contributors to hip motion, their lack of complete recovery following surgical incision may explain the postoperative reductions in hip joint biomechanical parameters. Limitations of the current study include a relatively small sample size and a large variability in postoperative test times, ranging from eight to thirty-two months.

SIGNIFICANCE:
The findings of the present study could aid in exposing the reasons for which the hip mechanics of FAI patients during gait are not restored postoperatively, and thus contribute to the development of better surgical techniques and rehabilitation programs.

REFERENCES:

Table 1. Hip variables found to be statistically significantly different between the control (CON), preoperative FAI (PRE) and postoperative FAI (POST) participants. Values expressed as mean (standard deviation).

<table>
<thead>
<tr>
<th>Variables</th>
<th>CON</th>
<th>PRE</th>
<th>POST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angles (°)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frontal Plane ROM**</td>
<td>17.8(2.9)</td>
<td>14.3(2.6)</td>
<td>14.3(2.7)</td>
</tr>
<tr>
<td>Sagittal Plane ROM**</td>
<td>51.5(2.7)</td>
<td>47.4(3.6)</td>
<td>46.8(4.6)</td>
</tr>
<tr>
<td>Moments (Nm/kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Abduction**</td>
<td>-0.79(0.16)</td>
<td>-0.68(0.11)</td>
<td>-0.61(0.07)</td>
</tr>
<tr>
<td>Peak Lateral Rotation**</td>
<td>0.19(0.07)</td>
<td>0.14(0.03)</td>
<td>0.08(0.04)</td>
</tr>
<tr>
<td>Power (W/kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Generation**</td>
<td>1.65(0.43)</td>
<td>1.45(0.21)</td>
<td>1.07(0.18)</td>
</tr>
</tbody>
</table>

For all variables: p ≤ 0.017 for angles; p ≤ 0.025 for moments and powers.
* Significant difference between CON and PRE groups.
** Significant difference between CON and POST groups.

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