Femoral torsion in patients with Blount’s disease
A PREVIOUSLY UNRECOGNISED COMPONENT

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In 1937 Blount described a series of 28 patients with ‘Tibia vara’. Since then, a number of deformities in the tibia and the femur have been described in association with this condition.

We analysed 14 children with Blount’s disease who were entered into a cross-sectional study. Their mean age was 10 (2 to 18). They underwent a clinical assessment of the rotational profile of their legs and a CT assessment of the angle of anteversion of their hips (femoral version). We compared our results to previously published controls. A statistically significant increase in femoral anteversion was noted in the affected legs, with on average the femurs in patients with Blount’s disease being 26° more anteverted than those in previously published controls.

We believe this to be a previously unrecognised component of Blount’s disease, and that the marked intoeing seen in the disease may be partly caused by internal femoral version, in addition to the well-recognised internal tibial version.

Blount, in his original paper of 1937 entitled ‘Tibia vara’ described the salient clinical and radiological features of the condition that was later named after him.1 He described varus angulation just distal to the knee joint, tibial bowing and shortening, laxity of the knee joint and ‘internal rotation of the tibia on the femur’. He also noted a number of radiological anomalies, such as a beak-like projection of the proximal medial tibial metaphysis, sloping and deficiency of the medial part of the proximal tibial epiphysis, increased thickening of the medial tibial cortex and premature fusion of the medial part of the proximal tibial growth plate in older children.

Subsequently, other authors have noted varus deformity of the distal femur, especially in adolescent Blount’s disease.2,4 In younger children, a valgus deformity of the distal femur has been noted.3,5,6 Additional joint deformities have also been noted, with posteroomedial depression of the joint line,7 and MRI studies8 have shown compensatory thickening of the medial meniscus and articular cartilage in the medial compartment. A compensatory valgus deformity of the ankle has also been noted.4

Internal torsion of the tibia is a well known and obvious feature of Blount’s disease and has been noted by most authors.1,5,9,10 Kessel,11 in an elegant experiment, showed that relative overgrowth of the normal fibula from the more posteriorly sited proximal tibiofibular joint to the more anterior distal tibiofibular syndesmosis, resulted in internal tibial version. However, we have noted some patients with Blount’s disease have persistent intoeing despite full correction of their internal tibial version (Fig. 1). We hypothesised that internal femoral version might play a significant role in Blount’s disease. Abnormal internal version of the femur has not been previously described in this condition to our knowledge, therefore we undertook a cross-sectional study looking at rotational profiles and femoral anteversion angles in patients with Blount’s disease.

Patients and Methods
Ethical approval for the study was obtained from institutional and national ethical review boards. Between May 2006 and May 2008, all patients who were diagnosed with Blount’s disease on clinical and radiological criteria either presenting for the first time or seen for follow-up in the orthopaedic department of Ngwelezana Hospital were entered prospectively into a database. This allowed us to perform a cross-sectional study looking at femoral anteversion and its correlation with internal and external rotation of the hip.

During this period 21 patients with Blount’s disease were seen; data collection was incomplete in seven, leaving 14 in the study. These
14 children were assessed by review of their previous treatment, clinical assessment of the rotation profile of their legs and CT assessment of their femoral version. All were Zulu children; their mean age was 10 (2 to 18); the majority (ten children) were between seven and 11 years old. There were seven boys and seven girls, with nine cases of infantile and five of adolescent Blount’s disease. Eight of the infantile cases and one of the adolescent cases were bilateral, giving a total of 23 knees in the study group. Nine of the 14 children (64%) were considered obese (i.e. above the 95th percentile weight for age).

Corrective surgery had been performed in 12 children (19 knees) and two were awaiting a bilateral upper tibial osteotomy. An older child (aged 12) had undergone an upper tibial osteotomy and was awaiting further double elevating osteotomy. These operations had been performed at a mean of one year and seven months (3 months to four years) before the clinical and CT assessments. In the group of children who had previous surgery there were eight with a simple upper tibial osteotomy and four with a double elevating osteotomy. This latter procedure was performed in a similar way to that described by van Huyssteen et al.12 with a physiodesis of the lateral side of the proximal tibia but without internal fixation apart from staples for the physiodesis. Of these four children, one had an upper tibial osteotomy prior to the double elevating osteotomy. This latter procedure was performed in a similar way to that described by van Huyssteen et al.12 with a physiodesis of the lateral side of the proximal tibia but without internal fixation apart from staples for the physiodesis. Of these four children, one had an upper tibial osteotomy prior to the double elevating osteotomy. All the upper tibial osteotomies and double elevating osteotomies involved correction or overcorrection of the internal tibial version, but none had any procedure performed on the femur. We therefore felt that it was appropriate to study femoral version in these children.

A rotational profile of the legs was performed by assessing the foot progression angle, the thigh/foot angle (tibial version) and the rotational arc of the hips. The latter two were evaluated according to the method described by Staheli.10 The thigh/foot angle was assessed with the child lying prone on a couch, with the tibia held vertically and the axis of the foot was measured with a goniometer in relation to the axis of the ipsilateral femur. The rotational arc of the hips was assessed in the prone position with the pelvis horizontal, the knee flexed 90° and both hips internally rotated and then externally rotated together. Measurements were made with a goniometer with the vertical tibia acting as neutral (0°). A clinical assessment of hip antversion was not performed because of the difficulties of assessment in the obese child.13 The rotational profile can be used to assess the incidence of femoral version and according to Staheli et al.,14 values of internal rotation > 2 SD and external rotation < 2 SD suggest femoral version.

Rotational profiles were performed on a control group of 32 Zulu children (24 boys and eight girls) to establish the norm for our population of Blount’s cases. Measurements were made on children being seen in the paediatric outpatient department with a variety of minor ailments, mostly respiratory. These children were similarly assessed, with the foot progression angle, the thigh/foot angles and the rotational arc of the hips being recorded. These data were then used to compare with the rotational profiles assessments by Staheli et al14 in North American children.

CT assessment of femoral version was performed by taking a number of transverse CT cuts through the hips and distal femurs with the child lying supine. These axial CT

Fig. 1a
Persistent intoeing after correction of tibial varus deformity by double elevating osteotomy.
images were then assessed to determine femoral version, which equates to hip anteverision. Hip anteverision angles were determined by the method advocated by Murphy et al. In this method the axis of the femoral neck is determined from a line joining the centre of the head to a point at the centre of the base of the neck. The angle between this line and a line joining the posterior aspects of the medial and lateral femoral condyles is measured (Fig. 2).

**Statistical analysis.** Anteverision angles and rotational profiles were compared on a graph using a 2 SD range. This is the only technique possible, as the original data from Staheli et al are not available, and the numbers of patients available for each age range are small. The reproducibility of the CT anteverision measurements was tested using correlation coefficient.

**Results**

**CT anteverision angles: inter-/intra-observer error.** Measurements of the anteverision angles were made twice by two of the authors (JJA, PR). They were blinded to previously recorded rotational profiles in an attempt to reduce bias. The intra-examiner correlation coefficient was 0.96 for JJA (95% CI 0.93 to 0.98) and 0.96 for PR (95% CI 0.93 to 0.99). The inter-examiner correlation coefficient was 0.98 (95% CI 0.97 to 0.99). These results suggest a reliable measurement technique, and we used the mean of the four results as the CT anteverision measurement for an individual femur.

The CT assessments of anteverision of the hip are shown in Figures 3 and 4. The mean anteverision for the 23 legs was 50° (10° to 80°). None of the children had retroversion of the hip. Of the 23 hips, 20 (87%) had an anteverision angle greater than that expected and an average 26° greater than the norms established by Staheli et al. Of the 23 hips, 17 (74%) had anteverision angles > 2 SD from the normal, and these could be termed torsional deformities. In the adolescent children 17 of the 20 (85%) were outside the 2 SD. The children with bilateral Blount’s disease tended to have similar anteverision angles in both hips. Of the five children with unilateral disease, two had a difference of anteverision angle between affected and unaffected hips of > 30°, and two had very similar anteverision angles (Fig. 4). As the majority of our data fall outside the 95% confidence interval (CI) we have evidence (on the basis of a limited sample) that Blount’s femurs are different from the previously published normals.

**Rotational profile of normal Zulu children.** The rotational profiles of the control group of normal legs in Zulu children were comparable to those reported by Staheli et al. Figure 5 shows external rotation of the femur in the children with normal legs and in the children with Blount’s disease, with Staheli et al’s range shown as lines. This graph shows that 89% of adolescent Blount’s legs were outside 2 SD of Staheli’s data, and 80% of ‘normal’ legs in the same age range were within 2 SD of Staheli’s data. This suggests that there was no significant racial difference in anteverision angles between Zulu children and the North American children studied by Staheli et al. We therefore thought it was reasonable to compare the anteverision angles of our Blount’s cases with the norms established by Staheli et al.

Tibial version was assessed by measuring the thigh/foot angle, and of the 17 legs previously operated on (with an upper tibial osteotomy, a double osteotomy or both) and not awaiting repeat surgery, all showed correction of internal tibial version, with a mean external version of 5° (Table I). As anticipated, all the six legs in three patients awaiting surgery showed some internal version of the tibia.
Discussion
Staheli\textsuperscript{17} defined version as being within 2 SD and torsion as the abnormal state, with the rotation of the bone being > 2 SD. In our series of 23 legs of patients with Blount’s disease, 15 had internal femoral torsion, with anteversion angles > 2 SD (> 50°). We have used Staheli’s definitions throughout this study, but many authors use the terms ‘version’ and ‘torsion’ interchangeably.

Anteversion of the hip is related to femoral version, with increasing anteversion being associated with increasing internal femoral torsion. Indeed, Fabry et al\textsuperscript{15} stated the terms ‘anteversion’ and ‘internal femoral torsion’ could be used synonymously. Uncompensated significant internal femoral version (marked femoral anteversion) will be seen clinically as intoeing during gait analysis.\textsuperscript{18} Staheli et al\textsuperscript{14} produced a considerable amount of data on the normal ranges of hip rotation in children, and these were used for comparison with our Blount’s cases. We were concerned that these norms were taken from studies in North America and might not reflect the rotational profiles of black Zulu children. However, the rotational profiles of our small control group of Zulu children with normal legs were not significantly different from those published by Staheli et al\textsuperscript{14}, implying that there are no significant differences in anteversion between Zulu and North American children.

Anteversion of the hip has been studied by many authors and can be measured by clinical, radiographic and CT means.\textsuperscript{13,15,16,18,19} Ruwe et al\textsuperscript{13} showed that clinical assessment can be accurate when compared with radiological and CT methods. However, clinical assessment is less reliable in obese patients,\textsuperscript{13} and in keeping with most studies of Blount’s disease, nine (64\%) of the 14 children in our study group were obese, and hence we felt that anteversion would be more accurately assessed by CT.\textsuperscript{20,21}

There are several methods of measuring hip anteversion using CT. Murphy et al\textsuperscript{16} showed that the angle subtended by the line joining the two most posterior points of the medial and lateral femoral condyles with that joining the centre of the femoral head and the centre of the base of the neck was the most accurate method of performing CT assessment of hip anteversion compared to direct measurements of femoral specimens. This was the method that we used. However, even with this method it can be difficult to gauge the axis of the neck of the femur in children under three years of age, where the centre of the base of the femoral neck is ill defined. Each observer (PR and JJA) made two blinded measurements of the anteversion angles in all the hips of the 14 patients with Blount’s disease, but intra- and inter-observer error was negligible, and the mean of the four assessments for each hip was used as the anteversion angle.

We compared the angles of hip anteversion of the hip in our patients with Blount’s disease with those in normal children.\textsuperscript{15} The study by Fabry et al\textsuperscript{15} using the Dunlop-Shands method of radiological assessment showed an average of

Table I. Comparison of mean tibial version (range) and mean foot progression (range) angle between legs awaiting operation and those assessed post-operatively

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<thead>
<tr>
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<th>Pre-operative assessment</th>
<th>Post-operative assessment</th>
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<tbody>
<tr>
<td>Number of legs</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Tibial version (°)</td>
<td>-19 (Internal) (10 to 45)</td>
<td>+5 (External) (0 to 25)</td>
</tr>
<tr>
<td>Foot progression angle (°)</td>
<td>21 (Intoeing) (10 to 65)</td>
<td>1 (Intoeing) (20 to 10)</td>
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24.14° anteversion in children, with a progressive decrease with increasing age, from 31.13° in one-year-old children to 15.35° in 16-year-olds. The CT assessment of anteversion we used and the Dunlop-Shands method may not be strictly comparable, as the latter is based on a central axis line through the neck of the femur, and this line does not correspond to the proximal femoral axis line used in Murphy’s method.16 It is likely that the radiological method used in Fabry’s study underestimates the angle of anteversion by an average of 10°.16

Gelberman et al18 showed that in children with intoeing, two-thirds of the cases were caused by marked femoral anteversion. The remaining children with intoeing had a normal angle of anteversion and could be differentiated by clinical assessment of the hip rotation in flexion. In their study group of 23 patients with intoeing, all had markedly increased internal rotation and limited external rotation of the hip when assessed with the hip in extension, but in about one-third of patients, external hip rotation was equal to or greater than internal rotation when assessed with the hip in flexion. Thus intoeing was secondary to marked femoral anteversion in most children, but, in approximately one-third, it was caused by tight or contracted soft tissues about the hip. We assessed rotation of the hip using a standard method.10 In retrospect, measurements of the arc of rotation in flexion and extension might have given a better assessment and might clinically have differentiated those patients with normal anteversion angles.

The majority of our patients had undergone surgery to the tibia which involved some degree of correction of the internal tibial version that is characteristic of Blount’s disease. Therefore, our measurement of the thigh/foot angle only reflected the corrected tibial rotation achieved post-operatively. No procedures were performed on any of the femurs, and we regarded the femoral rotational profile and the CT anteversion angles that we measured as valid and accurate assessments of the femoral version/hip anteversion in these patients.

Our results suggest that in adolescent patients with Blount’s disease there are significant changes in the angles of the hip, with 85% being outside 2 SD. Our results failed to confirm this in children who were under four years of age. We are unable to explain this finding of marked femoral internal torsion. Obesity is a well-known association with adolescent Blount’s disease.22 However, a study has shown that obese adolescents have reduced angles of anteversion, and this is thought to contribute to their increased risk of slipped upper femoral epiphysis.23 It is interesting to speculate that this increased anteversion is an effect of Blount’s disease and not a cause, as in two children in our study group aged two and three years, respectively, the femoral anteversion angles were normal, suggesting that femurs develop internal version as an effect of Blount’s disease. Further evidence in support of this is that a late-presenting eight-year-old child with infantile Blount’s disease awaiting surgical correction had the most extreme hip anteversion angles in the series. Also, the two adolescent patients with unilateral Blount’s disease who were treated in their teens with tibial osteotomy had large differences in the anteversion angles between their normal and their abnormal hips. It is logical to assume that, following early correction and possible cure of infantile Blount’s disease with an upper tibial osteotomy, femoral anteversion will remain normal. We intend to follow this up with a longitudinal study.

We have already addressed some of the limitations of our study but we are aware of a further source of error in the measurement of hip rotation in the presence of a varus angulation of the tibia. Varus deformity of the proximal tibia will give some inaccuracy in these measurements when the tibia itself is used to assess the arc of rotation, tending to increase the measurement of external rotation and reduce the measurement of internal rotation. Hence some of the measurements that we recorded in the three patients with Blount’s disease awaiting surgery may be inaccurate.

Our results suggest that the marked intoeing seen in many cases of Blount’s disease may be caused partly by internal femoral version, in addition to the well-recognised internal tibial version. We would like to suggest the following as a result of this study:

1. A rotational profile should be part of the clinical assessment of all patients with Blount’s disease.
2. CT assessment of anteversion should be considered to quantify this accurately.
3. Overcorrection of the tibial internal version (to correct the added femoral version/torsion) should be considered when performing a tibial osteotomy in patients with marked femoral internal version (torsion).
4. Persistent intoeing after tibial corrective surgery may require derotation ostetomy of the femur for persistent internal femoral torsion.

The authors wish to thank Dr. H. Sanders from the University of Plymouth for her advice regarding statistical analysis.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


THE JOURNAL OF BONE AND JOINT SURGERY