**Knee Varus Moment Impulse Change through the Development of Adolescent Tibia Vara**

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**Introduction**

The gait change during the development of adolescent tibia vara (ATV) has never been reported in the literature. The purpose of this study is to report the kinetic and kinematic data from a series of five consecutive gait evaluations in a 12.4-year-old boy in whom left hemiplegic cerebral palsy (CP) was associated with ATV in the right lower limb.

**Clinical Significance**

ATV can be detected before the appearance of gross deformity through the measurement of peak varus moment and the varus moment impulse of the knee. Early intervention including strict body weight control and possible hemiepiphyseal stapling could be considered to prevent growth plate failure at the proximal tibia.

**Methodology**

A 12.4-year-old boy weighing 97.5 kg was diagnosed with left hemiplegic CP. He received five gait evaluations at 5.2, 7.2, 9.9, 11.9, and 12.4 years of age, respectively (Fig. 1). Kinematic and kinetic analyses of gait were performed using a six-camera Motion Analysis System (Motion Analysis Inc., Santa Rosa, CA, USA) and two Kistler force plates (Kistler Instruments AG, Winterthur, Switzerland). Associated software (Orthotrak 5.0, Motion Analysis Inc., Santa Rosa, CA, USA) allowed assessment of the hip-, knee-, and ankle-joint centers with subsequent calculation of the dynamic mechanical axis through the gait cycle. The inverse dynamics approach was used to integrate the body segment parameter and kinematic and force plate data to solve the resultant moment at the knee joints. The pure moment was calculated without normalization by body weight. The moment impulse signifies the effect of a thrust and is a function of the magnitude of the moment experienced and the duration the moment is applied over each gait cycle. The moment impulse was calculated as the area under moment/time curve. Because the moment calculations have different means and standard deviations at different ages and body weights, the Z-scores (standard scores) were used to compare the relative standings of items from distribution of normal children. The Z-score was expressed in units of standard deviations from the normal mean. A positive Z-score is higher than the normal mean and a negative Z-score is lower than the normal mean.

**Results**

The peak varus moment of the right knee before the onset of ATV was 24.2 Newton-meter (Nm) (Z-score = 4.12) at the age of 9.9 years and 44.9 Nm (Z-score = 7.69) when the patient was 10.9 years old. Meanwhile, the varus moment of the left knee was 13.9 Nm (Z-score = 1.51) at 9.9 years and 10.6 Nm (Z-score = 0.63) at age 10.9 years. After the onset of clinically evident ATV, the right knee peak varus moment was 73 Nm (Z-score = 10.88) compared with 25.3 Nm (Z-score 2.99) for the left side when the patient was 12.4 years old with a body weight of 97.3 kg (Fig. 2). The varus moment impulse calculated by summation of varus moment through the gait cycle showed a marked increase from 720 Nm-% (Z-score = 2.63) at

9.9 years of age to 3,227 Nm-% (Z-score = 10.6) at 12.4 years of age (Fig. 3). Kinematically, 9° of peak varus angulation was noted at stance phase when the patient was 10.9 years old without any right knee complaints.

**Discussion**

The varus moment is the primary determinate of the distribution of load between the medial and lateral plateaus of the knee. In patients with high tibial osteotomy for varus gonarthrosis, those with low preoperative varus moment had substantially better clinical results than those with high varus moment (1). Because of the gait problems associated with hemiplegic CP, our patient underwent five gait evaluations before and after the onset of ATV. In the kinematic gait analysis 13 months prior to symptomatic ATV, the knee varus angle increased up to 9° in stance phase while there were no signs of right knee pathology. Obese patients with ATV may have minor varus of the knee go unnoticed until the pain or shortening of a significant deformity has brought it to their attention (2). Gait analysis is a relatively sensitive modality for early detection of coronal plane deformity in ATV through the measurement of the varus knee moment. The significant gait changes before and after the onset of clinically evident tibia vara were an increase of the peak knee varus moment from 44.9 Nm to 73.0 Nm and an increase of the varus moment impulse from 720 Nm-% to 3,227 Nm-% in a 1-year-5-month period (Fig. 2, Fig. 3). There are no documented data in the literature for the required moment or moment impulse to develop the growth disturbance in the growing human physis. The peak varus moment measurements of the right knee were at the upper limit of normal before the patient was 9.9 years old. Based on the moment data, there also seems to be a failure point in the magnitude of the knee varus moment, which leads to rapid increase in the deformity. Based on this single case, we cannot give a specific number for this failure, but further research with more patients early in the ATV process may be able to determine this critical knee varus moment. The primary measures should be the peak varus moment and the varus moment impulse, which probably rise high before significant bony deformity occurs. This might allow an earlier and simpler treatment protocol for ATV compared with complex late-stage tibial osteotomies.

**References**


1. Prodromos CC, Andriacchi TP, et al. A relationship between gait and clinical changes following high tibial osteotomy. J Bone Joint Surg Am, 67: 1188-1194, 1985.
2. Beskin JL, Burke SW, et al. Clinical basis for a mechanical etiology in adolescent Blount's disease. Orthopedics, 9: 365-370, 1986.


Figure 1. X-ray: At age of 9.9 years, the mechanical axis (M.A.) of right knee was 0° (left). At 12 years old, the M.A. measured 19° varus (middle). Three months later, the M.A. increased to 29° varus (right). Gross photo: gradual development of ATV.

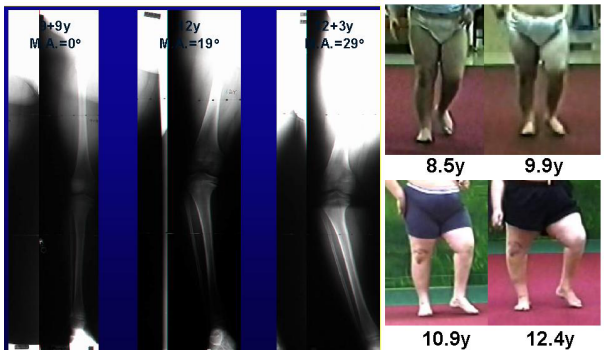


Figure 2. Pure external varus moment of knee in gait cycle: dramatic increase of right knee varus moment (right) compared with relatively lower measurement from the left knee (left).

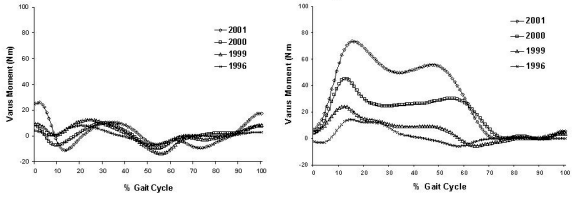


Figure 3. The Z-score column charts of pure varus moment impulse