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Correlation of the torsion values measured by rotational profile, kinematics, and CT study in CP patients

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A R T I C L E I N F O

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A B S T R A C T

Background: The purpose of study was to analyze correlations between bony torsions measured by Staheli's rotation profile, computed tomography (CT) torsional study, and gait analysis in patients with cerebral palsy (CP).

Materials & method: The study group comprised of 26 children with CP (spastic diplegia, Gross Motor Function Classification System (GMFCS) 1–2, mean age 12.6 years) with torsional deformities. All subjects were assessed by examining: 1) rotational profile [internal rotation (IR) and external rotation (ER)], 2) CT torsional profile [femoral anteversion (FAV) and tibial torsion (TT)], and 3) gait analysis [mean hip rotation (HR) and mean knee rotation (KR)]. Statistical analysis was performed using the Pearson correlation test.

Results: In the femur, there was good correlation between FAV and Staheli's rotational profile of IR and ER (Pearson correlation coefficient (PC = 0.69, 0.52, $p < 0.05$)). ER correlated very strongly with mean HR during gait (PC = 0.8, $p < 0.05$). There was, however, poor correlation between HR and IR ($p > 0.05$), and between HR and FAV ($p > 0.05$).

In the tibia, mean KR correlated well with thigh-foot angle (TFA) (PC = 0.72) and CT tibia torsion (TT) (PC = 0.62). TT also correlated with TFA (PC = 0.62).

Conclusion: Gait analysis and Staheli's rotational profile reflect both static and dynamic factors of gait abnormalities. However, CT study reflect static factor primarily. Dynamic factors tend to influence the measurements of the femoral torsion only due to large rotational arc of hip joint. In surgical planning, it must be considered that HR sometimes does not correlate with CT anteversion angle. Similarly, it must also be considered that KR correlates well with TFA and CT TT angle.

1. Introduction

Torsional deformities in children with cerebral palsy (CP) children are very common. Medial femoral torsion, or increased anteversion, causes the feet to point inward, which is associated with cosmetic and functional problems. Internal foot progression angle in the swing phase of gait results in obstacles for foot clearance and frequent tripping [1–4]. In the stance phase, it results in lever arm disease, causing muscle fatigue or pain during long-distance walking [5,6]. Lower extremity malalignment can be corrected by femoral derotation osteotomy (FDO) or tibial derotation osteotomy (TDO) with good outcomes in both short and long term follow-up studies even with some debate on the recurrence in young population under 10 years of age [7–9].

When planning for osteotomy, it is essential to measure the degree of torsion [10]. Physical examination, gait analysis and computed tomography scanning (CT) are commonly used to measure femoral or tibial torsion (TT) [11]. The measured values for each test, however, are not always consistent with each other [11–13]. A study by Aktas demonstrated that CT measurements of femoral anteversion (FAV) and physical examination data failed to predict hip rotation (HR) during gait [12]. Such discordance often leads to hesitation from the surgeon when planning for surgery, with difficulty in determining the degree of derotation required. The purpose of this study was to analyze correlations among the measured torsion values of physical examination, gait analysis, and CT torsional study for surgical planning in patients with CP.

2. Materials and methods

2.1. Study subjects

The study group involved 26 children with CP spastic diplegia with torsional deformities. The patients were subjected to physical

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examination, gait analysis, and CT torsional study prior to surgery. Mean age was 12.6 years (range, 6–16 years old). There were 12 female and 14 male children. Most of the children were Gross Motor Function Classification System (GMFCS) level 1 or 2, and one patient was classified as GMFCS level 3 [14]. Patients with unstable knee joints were excluded. Physical examination, gait analysis, and CT were preferably performed on the same day or at least within a week. We analyzed the remaining legs of 26 children.

2.2. Study methods

2.2.1. Physical examination

Staheli's rotational profile was measured, and the internal and external rotation (IR and ER) of the hip joint reflecting femoral torsion and the thigh-foot angle (TFA) reflecting tibial torsion were used for data analysis. The IR, ER and TFA were measured in the prone position with the knee joint bent 90° and ankle in neutral dorsiflexion [15]. The angle was measured using a goniometer by an orthopedic resident and gait lab staff.

2.2.2. Gait analysis

For gait analysis, 6 Eagle camera systems (Motion Analysis®, CA, USA) and 2 AMTI force plates (Advanced Mechanical Technology Inc., Watertown, MA, USA) were used. Passive reflective markers were attached by the modified Helen Hayes method. Patients were allowed to walk at a comfortable speed. The rate of motion capture was 120 Hz (120 frames per second). The data obtained was processed using Eva Real Time (EvaRT, Ver 4.2, Motion Analysis®, CA, USA) and Orthotrak (Motion Analysis®, Santa Rosa, CA, USA) software. Among the kinematic data, mean rotational values of the pelvis (PR), hip (HR), knee (KR), foot (FR), and foot progression angle (FPA) in the transverse plane were used for the analysis. KR is defined as difference in the degree of rotation between the distal femoral marker and distal tibial marker in the transverse plane during gait, and is the representative value for tibial torsion during gait.

2.2.3. CT torsional study

Radiographic measurements of bony torsions were performed using CT (Somatom sensation 16, Siemens, Germany) and M-view of Picture, Archiving & Communication System (PACS). For CT scanning, subjects were in a supine position with legs internally rotated by 5°. The legs were immobilized with supporting sponge rods during scanning. Femoral torsion (femoral anteversion, FAV) was defined (Fig. 1) as the angle between a line connecting the centers of the femoral head and neck, and another line connecting the posterior margins of the medial and lateral femoral condyles on the transverse CT images of PACS environment [16]. Tibial torsion (TT) was defined as the angle between a line connecting the posterior margins of the medial and lateral tibial condyles and another line connecting the tips of medial and lateral malleoli on transverse CT images [17–19].

3. Statistical analysis

The correlations between the torsion angles measured by physical examination (IR, ER, TFA), the CT scan (FAV, TT), and the kinematic data obtained by gait analysis (HR, KR) were statistically evaluated using Pearson correlation (PC) tests. The statistics package, SPSS for Windows (version 20.0, SPSS Inc., Chicago, IL, USA) was used for determining the significance based on the validated *p*-value of 0.05.

4. Results

The torsion values measured by the various methods are shown in Table 1. Internal torsion was designated as a 'plus' sign, and external torsion as a 'minus' sign.

In regard to the femur, the mean hip joint IR was 54.6 ± 16.9° (range, 25–80), and the mean hip joint ER was 38.5 ± 15.9° (range, −70–0). The mean CT medial femoral torsion was 27.9 ± 15.7° (range, −18–58) and the mean kinematic HR was 10.3 ± 13.0° (range, −10.5–43.8). FAV showed a strong correlation with IR (PC 0.69, $p < 0.05$), and moderate correlation with ER (PC 0.52, $p < 0.05$). However, there was no correlation between FAV and HR. Also, there was a high level of correlation between HR and ER in (PC 0.80, $p < 0.05$) (Table 2, Fig. 2). On the other hand, there was a poor correlation between IR and HR (PC 0.34, $p > 0.05$).

In regard to the tibia, the mean TFA was external 13.3 ± 15.7° (range, −40–10), the mean TT was external 24.5 ± 14.6° (range, −57–-2), and the mean KR was external 14.4 ± 15.7° (range, −43.4–18.9). There was a high level of correlation between TFA and KR (PC 0.72, $p < 0.05$). In addition, there was a strong correlation between TFA and TT (PC 0.62, $p < 0.05$), between KR and TT (PC 0.62, $p < 0.05$) (Table 3, Fig. 2).

5. Discussion

Unlike able-bodied children, torsional deformation in children with CP does not improve with growth. Correcting the torsional deformity improves energy efficiency in walking. For the success of corrective osteotomy, accurate evaluation of the deformation before surgery is important. As coronal, sagittal, and transverse deformations coexist in CP, accurate evaluation is difficult [20–22]. Currently, physical examination (rotational profile), CT torsional study, and gait analysis are commonly used in the clinic to measure torsion. According to Murphy, CT is known to be the most accurate radiographic test [12]. Sonography is currently widely used in children who have more cartilage [23].

Some surgeons have made surgical decisions regarding the degree of

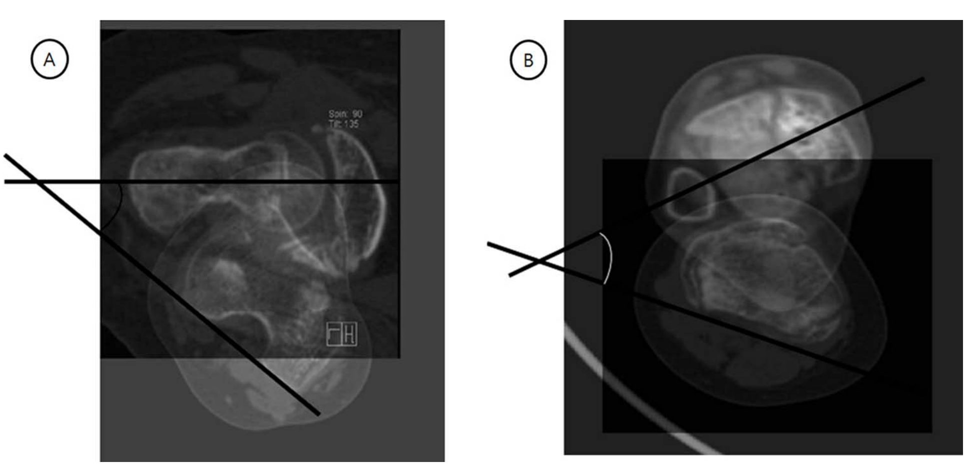

Fig. 1. Measurement of FAV (femoral anteversion) and TT (Tibial torsion) on the CT images.
A) FAV was defined as the angle between a line connecting the centers of the femoral head and neck, and another line connecting the posterior margins of the medial and lateral femoral condyles. B) TT was defined as the angle between a line connecting the posterior margins of the medial and lateral tibial condyles and another line connecting the tips of medial and lateral malleoli on the transverse CT images.