Mathematical interpretation techniques: The marker trajectories are used to define a 3D biomechanical model consisting of seven rigid segments: tibia, talus, calcaneus, navicular, 1st and 5th metatarsal and hallux. The position of talus, which cannot be marked directly, is determined by localizing the axes of the tibiotalar and talocalcaneal joint using minimization methods similar to [1]. Additionally *functional* segments are defined: medial arch, mid- and forefoot. *Functional* means that they are flexible and overlap with other segments, but they are very helpful to understand combined motions, which include several joints.

The attitude of each segment can be described relative to the static global system or to the more proximal located segment. In the second case either an averaged normal or a individually adjusted geometry of the proximal segment can be assumed. Euler angles are in no case suitable to describe motions of a multi-segmented foot model and rotational angles have to be declared together with a single and unequivocal defined axis to obtain comprehensive information about normal and pathological foot function.

Results

The carefully adjusted motion capturing system and the controlled marker placement allow a reconstruction of motion within sufficiently low error bounds. The kinematics are described by seven static and 34 dynamic values, but in general a certain problem can be identified and quantitatively assessed using up to 12 specific values found by automated recognition of typically changed patterns.

Kinetics are shown as 3D projections of ground reaction forces and plantar pressure into the computer animation of the moving foot, which allows a rough visual impression of external and internal loads. The detailed view onto the foot makes new insights in the action and interaction of the different segments possible. So far 16 normal subjects and 60 patients with different deformities have been examined (planovalgus, cavus, drop foot, spastic clubfoot, tendo-achilles rupture, diabetic foot and partial amputations). Examples: Fig. 3 shows the arch angle (angle between the lines from medial calcaneus and head MT I to navicular) of a plano valgus — the right arch is fairly stiff; Fig. 4 is the forefoot supination of a spastic club foot — the right foot is strongly pronated.

Discussion

A realistic understanding of malfunctions located inside the foot is impossible without detailed information about the movement between the anatomical segments. Therefore, the highest available number of markers and model segments is desired, although the difficulties of motion capturing will increase [2] and data interpretation demands a sophisticated knowledge of coordinate systems. In our study these problems are handled by new techniques of marker placement, an adjusted capturing system and the description of combined motions using functional segments. This allows a more detailed view than other existing foot models [3, 4, 5]. The model has passed several test for reliability but as long as the model simplifies the real structure a complete validation is permitted. Limitations of this method are severe deformities and feet of children younger than 6 years.

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Assessment of methods to describe the angular position of the pelvis during gait in children with hemiplegic cerebral palsy

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Introduction

For clinical gait analysis, the angular position of the pelvis is described by its obliquity (up/down), tilt (anterior/posterior) and rotation (internal/external). Generally, these three angular displacements are computed based on Eulerian angles [1]. This approach requires that the order of the computation be specified, for example, compute obliquity then tilt then rotation or compute tilt then obliquity then rotation. The order of the computation sequence affects the magnitude of the resulting angles. For clinical gait analysis, the pelvic angles have commonly been computed using Eulerian angles based on a tilt-obliquity-rotation (TOR) sequence [2]. It has been observed that, on occasion, the quantitative pelvic data differs from the visual impression of the patient, specifically as related to obliquity [3]. Recently, Baker [4] has proposed an alternative rotation sequence for computing pelvic position via Eulerian angles, i.e. rotation-obliquity-tilt (ROT), that appears to address this conflict between quantitative results and visual impression. The purpose of this study is to examine the pelvic angles based on these two Eulerian angle rotation sequences (TOR and ROT) in a group of children with hemiplegic cerebral palsy (CP) and to compare the quantitative results with a video-based analysis.

Statement of clinical significance

A method that results in computed angles of pelvic obliquity that are in better agreement with clinical observations should benefit the interpretation of clinical gait data.

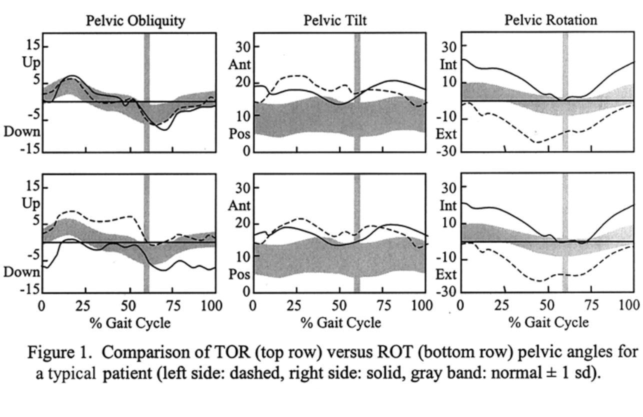

Figure 1. Comparison of TOR (top row) versus ROT (bottom row) pelvic angles for a typical patient (left side: dashed, right side: solid, gray band: normal ± 1 sd).

Methodology

A retrospective analysis was conducted of video and three dimensional (3D) gait data collected for 49 children with hemiplegic CP evaluated in the Motion Analysis Laboratory over the past 6 years (average age = 8 years, range 4–14 years, mean height = 125 cm, mean mass = 26 kg). To obtain a clinical impression of pelvic obliquity, rotation, and tilt, an experienced clinician watched video footage of sagittal and coronal views of each patient walking and rated pelvic position during single support as normal, markedly increased, or markedly decreased. In addition, pelvic angles were calculated from 3D gait data collected using a Vicon 370 motion analysis system (Oxford Metrics Ltd., Oxford, England) for three gait cycles for each subject. Pelvic angles were calculated from pelvic marker coordinates for TOR and ROT-based rotation sequences and average values during single support were computed. For comparison purposes, the angles were categorized as normal, increased or decreased (normal = within ± 1 standard deviation of normal). Concordance between angles calculated using the two quantitative methods was assessed using the kappa statistic.

Results

Results of the comparison of pelvic angles calculated using each rotation sequence are presented in Table 1. For tilt and rotation, excellent agreement ($k > 0.75$) between the two methods was found. For obliquity, poor agreement was found ($k < 0.4$). These results are illustrated by the case shown in Fig. 1. Further analysis of the subset of patients for which pelvic obliquity differed with computational method ($n = 21$, 43%), revealed 14% agreement with clinician scores for sequence TOR and 71% agreement for sequence ROT. Tilt (anterior) and rotation (absolute value) were significantly larger for this subgroup than for the rest of the patients: means of 19° versus 16° (SD = 6°) of tilt and 11° versus 6° (SD = 5°) of rotation, respectively (t-test, $P < 0.05$).

Table 1
Comparison of pelvic angles calculated using TOR vs. ROT-based methods ($n = 49$)

Pelvic angle	Agreement (%)	Kappa statistic	Kappa, 95% conf. interval
Obliquity	57	0.31	0.10–0.52
Tilt	96	0.85	0.71–0.99
Rotation	94	0.86	0.71–1.0

Discussion

The results of this study demonstrate that the two alternative Eulerian angle rotation sequences produce different measures of pelvic obliquity in a significant number (43%) of children with hemiplegic CP. In the patient group where the quantitative data are different than the visual impression of an experienced clinician, the ROT-based obliquity data more often agree with the clinician than does the currently-used TOR-based results. Little difference between the two quantitative approaches was noted with respect to the corresponding pelvic tilt or rotation angles. In summary, the ROT approach produced obliquity angles in better agreement with visual impression without affecting tilt or rotation angles. The data also show that differences between angles computed by the TOR and ROT approaches are related to the magnitude of the abnormal pelvic displacement. Consequently, the ROT-based Eulerian angle approach should also be examined as an alternative to the TOR-based approach in other patient populations such as myelomeningocele where large pelvic displacements are commonly seen.

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Relationship between body posture and standing equilibrium parameters in adolescent idiopathic scoliosis

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Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformation of the spine which is responsible for changes in the trunk and rib cage [1, 2]. Though it is believe that the spinal deformity and compensatory actions of the neurologic system are responsible to standing imbalance in AIS [3] instability in AIS has not yet been relate with postural parameters. The objectives are to test the hypothesis that: (a) some postural parameters are related to some standing instability parameters; and (b) that some of them are specific to AIS.

Statement of clinical relevance

Eventually, it may be possible to adapt body braces and spinal instrumentation to improve the scoliosis correction and increase standing stability IAS.

Methodology

The scoliotic group was formed by 21 girls of 12.3 ± 1.1 years while their height and weight were 152.1 ± 8.8 cm and 42.3 ± 6.9 kg, respectively. Their Cobb angle was $31.2 \pm 11.6°$. No patient was under treatment. The control group consisted of 23 able-bodied girls having an average age of 12.1 ± 1.1 years and a height and weight of 153.3 ± 9.7 cm and 42.4 ± 6.8 kg, respectively. No difference was found between the anthropometric parameters of each group. Eighteen anatomical landmarks were digitized on the head, shoulder girdle and pelvis by the pointer of a Flock of Bird system. Several length, height and relative angles such as frontal shoulder angle were calculated. Standing was tested using a force plate. There were three trials of 64 s at 64 Hz. The COM was determined from the COP values [6]. Sway area of the COP, mean COP_{ML} (medio-lateral) and COP_{AP} (antero-posterior) positions and the $COP-COM_{ML}$ and $COP-COM_{AP}$ were calculated. Pearson's coefficients of correlation were calculated between the stability and posture parameters. Those with a $P < 0.05$ were considered significant.

Results

The significant coefficients ranged between 0.43 and 0.82. In the able-bodied group, only trunk length was correlated negatively with sway area (-0.55) and positively with $COP-COM_{AP}$ (0.52). Table 1 presents the Pearson's coefficients of correlation for the scoliotic group. Sway area was positively correlated with the subjects' height and frontal angles. COP_{Ml} was negatively correlated with a position towards the left while a forward displacement of the COP_{AP} position was associated height. The COP–COM parameters were associated with some body posture position and relative angles. Posture parameters did not correlate with Cobb angle.