direction. The angle between the STT and SARA knee axes was 0.9º (2.3º) [Figure 1]. The SCoRE/SARA method was 208/210 times faster for computing hip centers/knee axes.

Discussion: The SCoRE/SARA and STT methods have been shown to be equivalent in a clinical setting. The SCoRE/SARA method is many times faster due to the computational methods used.

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P042

Comparison of electromyography in normal and simulated bowleg gait

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Summary: The study compared two modes of gait, normal walking and simulated bowleg walking in normal healthy adults in terms of electromyography (EMG) from eight muscles in the lower limbs. It was found that on average, the phases of muscle activity in normal gait were 0.7 times that of simulated bowleg gait but, the EMG power in normal gait was 2.6 times greater than the bowleg gait.

Conclusions: Muscle activity in simulated bowlegged gait appeared to be weaker in strength but longer in duration than normal gait. Further studies on patients with pathological bowleg would need to be studied to enhance the understanding of the EMG activity in this group.

Introduction: Bowleg gait (genu varus) is a common finding particularly in older people but it is also seen in normal children and apes. So far, muscle activity in such gait patterns has not been fully investigated. In elderly people, osteoarthritis is the major cause of bowleg gait. Other causes include Paget's disease, trauma, infection, tumours and rarely rheumatoid arthritis [1]. Understanding the muscle active patterns in bowleg gait is essential for optimal management, rehabilitation and evaluation of treatment outcomes. Most previous studies have examined the muscle activity pattern of the knee joint including quadriceps and hamstring muscles by surface EMG in bowlegged patients. In a few studies the knee muscle activity has been studied along with other leg muscles [2].

Materials and Methods: Fourteen normal healthy adults were studied using surface EMG. Subjects were asked to walk normally at their own pace and with a simulated bowleg gait. Their ages ranged between 20 and 45 years. The EMGs from eight major muscles, the gluteus maximus and medius, biceps femoris, rectus femoris, vastus lateralis, tibialis anterior, medial gastrocnemius and soleus were recorded. The data was acquired using Vicon® motion capture system (MX F40), two Kislter® force platforms and TSMI® EMG system. Each subject had 8 reflective markers placed on the pre-determined positions on the body. A custom designed program was used to synchronise the data for analysis to determine the relationships between gait and EMG activity.

Results: The biceps femoris and rectus femoris muscles showed prolonged phasic activity with reduced EMG power but the vastus lateralis and gluteus medius muscles showed increased phasic activity without any statistical difference in EMG power. The gluteus maximus muscle activity was prolonged with reduced power in the stance phase of simulated bowleg gait. In medial gastrocnemius, EMG power was decreased with no difference in phasic activity. Tibialis anterior and soleus muscles showed no statistical difference in phasic activity and EMG power between the two modes of gait.

Discussion: This study shows that the muscles around the knee, quadriceps and hamstrings, had more prolonged activity in the stance phase than any other muscles in simulated bowleg gait. In particular, rectus femoris muscle was active throughout stance phase. However, this may be due to the knees being more flexed in stance in the bow-leg gait. In order to confirm the above findings, studies should be carried out in patients with bowleg deformity.

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P043

Measuring three-dimensional knee rotations with skin markers

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Summary: The aim of this study was to evaluate the experimental sources of error associated to a general test of knee joint kinematics in-vivo. In particular, the interest was to assess how critically landmark identification, soft tissue motion and rotation axes estimation on the thigh affect the values of the measurements. Several different multi-marker clusters, including physical markers and calibrated landmarks, were analyzed during gait and elementary exercises of isolated hip and knee joint rotations. The addition of a few direct markers to the standard sets seems to enhance considerably the reliability with which surface clusters can track internal knee rotations.

Conclusions: Skeletal knee rotations can be fully mis-tracked when calculated from standard marker-sets. A medial epicondyle marker or a few additional markers on the distal thigh reduce the errors to a large extent.

Introduction: Despite the recently proposed protocols for gait analysis [1,2], the reliability of three-dimensional knee rotation measurements still remains an issue, also because of the lack of non-invasive validation techniques.

Materials and Methods: A volunteer (male, 29 years, 93 kg, 180 cm) was instrumented with the marker set of two standard protocols [1,3], the wand marker (Tw) being strapped with an elastic band with VELCRO® fasteners; four additional markers were placed in the mid thigh around Tw, according to [2], and at the antero-lateral (LP) and antero-medial (MP) ridges of the femoral groove, for a total of 38 markers. Motion capture was performed (Vicon Motion Systems, UK) in up-right posture and during level walking, hip internal/external rotation (IE hip) and flexion/extension followed by ab/adduction (FEAA hip) with the knee in full extension, knee internal/external rotation at 30º knee flexion (IE knee) and knee flexion/extension (FE knee). In addition to the standard Plug-in-Gait (PiG) [3] (with and without the Knee Alignment Device) and Total3Dgait (T3Dg) [1] protocols, different techniques were utilized for knee rotation calculations. By using the same femur anatomical reference frame [2], T3Dg was processed with the medial epicondyle marker (ME) left in place (T3Dg+ME) rather than reconstructed from the lateral thigh cluster (HC, GT, LE). This cluster was also utilized for SVD-based [4] calculations of the relevant technical frame by which anatomical landmarks and frames were defined and knee rotations calculated [5]. The cluster was further extended progressively with additional markers (Table 1). The hip joint center (HC) was always taken as defined by regression equations [6].

Table 1: Range (max–min) of knee internal/external rotation angles [deg] averaged over the six trials collected

Technique/Technical frame	Walking	Hip		Knee	
		IE	FEAA	IE	FE
T3Dg [1]	17.7	54.2	31.5	30.2	14.0
T3Dg + ME	11.3	8.0	3.8	12.6	13.6
SVD on HC, GT, LE (lat.epicond.)	18.4	54.1	31.4	30.2	15.2
SVD on HC, GT, LE, ME	12.8	24.2	11.7	18.3	14.6
SVD on HC, GT, LE, ME, LP, MP	12.1	18.8	8.9	16.3	14.9
SVD on C.A.S.T. markers [2]	14.4	33.5	16.3	24.1	12.9
SVD on HC, Tw, LE	17.8	36.6	19.4	27.1	17.1
SVD with all thigh markers	12.3	24.7	11.3	20.0	13.0
PiG [3] no KAD	18.2	28.0	13.9	25.2	32.6
with KAD	17.6	28.0	14.0	23.0	13.4

Results: Large erroneous values in internal/external rotation and much smaller in ab/adduction were found by all techniques (Table 1). This is best revealed in those exercises where rotation should be null (IE and FEAA hip). SVD-based best matching reduces this error considerably. Also according to physiological knee motion during gait [7], T3Dg+ME shows the most reliable results.

Discussion: Erroneous internal/external rotation at the knee can be as large as 55 degrees, though obtained for very large thigh rotations, not exercised in any standard motor task. Important reductions of this error can be obtained by including additional markers at the central and distal area of the thigh to be utilised for a multi-marker and SVD-based technical frame. In gait, the single best estimation of this rotation seems to be obtained by simply adding a marker at the medial epicondyle, though this is not viable in all subjects and not true for every motor task. Additional experiments will be necessary to confirm these preliminary observations.

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P044
Withdrawn

P045
Reliability of a three-dimensional upper limb movement analysis in children

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Summary/Conclusions: This study assessed both within and between session repeatability of a three-dimensional (3D) upper limb movement analysis in a normal pediatric population. Repeatability results are promising for future clinical implementation of the current movement protocol.

Introduction: While gait analysis has widespread use in biomechanical research and clinical applications, no consensus exists for 3D upper limb analysis. The aim of the study was to develop an upper limb model for 3D kinematic analysis, along with a movement protocol consisting of functional tasks to establish a full representation of the upper limb abilities. The reliability of 3 selected tasks was tested in a normal pediatric population.

Patients/Materials and Methods: Eight typically developing children (6 boys/2 girls, mean age 9.8±3.5 years) were tested on 2 occasions, 2 to 10 days apart. The movement protocol consisted of 3 tasks (reach forwards, reach to grasp a cylinder and hand to mouth), all performed with the non-dominant arm. To ensure maximum repeatability, children were seated in a custom made chair that allowed individualized reaching distance and height, and foot and back support. Three trials (4 repeats per trial) were captured for every task. A total of 17 retroreflective markers were placed over the child's trunk, scapula, humerus, forearm and hand in clusters of 3 to 4 markers. Bony landmarks were palpated and digitized during several static trials (CAST-method) [1]. The anatomical coordinate frames and joint rotation sequences were defined according to the guidelines from the International Society of Biomechanics [2]. Marker 3D tracking was done with 12 Vicon-cameras (Oxford Metrics, UK), and data was further processed using BodyMech (MOVE, Amsterdam) and Matlab. The angular movement cycles (waveforms) were time-normalized and the 2nd and 3rd repeat of every trial was used for statistical analysis. Similarity of the waveforms was assessed with the coefficient of multiple correlation (CMC), averaged for the total group [3].

Results: Reach forwards resulted in excellent repeatability for shoulder elevation and scapular rotation (mean CMC >0.92), good repeatability for shoulder axial rotations, elbow flexion-extension and scapular pro-retraction (mean CMC 0.82–0.91) and only fair repeatability for elbow pro-supination and wrist flexion-extension (mean CMC 0.58–0.74), both within and between sessions. Lowest values were found for waveforms from the shoulder plane of elevation, trunk rotations and wrist deviations (mean CMC 0.39–0.59). During reach to grasp, waveforms of shoulder elevation and scapular pro-retraction had excellent within and