with CP present varying gait patterns which affects the planning of interventions to improve gait. No studies have yet compared the effects of tuning on knee joint kinematics for different gait patterns in children with CP. This study investigates the effects of tuning on the stance phase knee kinematics in children with cerebral palsy and also compares the effects for three different gait patterns with extended knee gait in which the knee hyperextends during mid to terminal stance, flexed knee gait in which the knee is flexed throughout the stance phase and jump knee gait in which there is increased flexion in initial stance followed by normal to increased extension in mid to terminal stance.

Patients/Materials and Methods: Eight children with cerebral palsy (10 legs were considered) were included in the study of mean age (SD) 9 (2.9) years. All the children used rigid AFOs. Data was collected using Vicon 612 motion analysis system and two AMTI force plates. For all the children, gait analysis was performed with their original prescription of AFO-FC followed by tuning and then with the final prescription. Tuning was carried out using wedges and rockers to optimise the alignment of the GRF vector with relation to lower limb joints. For tuned and non tuned AFO-FCs, the absolute difference between selected knee variables of the children with CP and normal values [2] were calculated and were compared statistically (level of significance at $p < 0.05$).

Patients/Materials and Methods: Only peak knee extension during stance was significantly different for all children. However, while tuning increased the knee flexion at IC and peak knee flexion during stance in children with extended knee gait, both the variables decreased in the other two groups. Tuning optimised peak knee extension by increasing the flexion in first group and decreasing the flexion in the second group.

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O067

Functional measures of lower limb spasticity in stroke during gait

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Summary: Spasticity while walking was quantified by defining velocity threshold and gain index from a plot of muscle lengthening velocity against EMG activity. These parameters were derived for three lower leg muscles in both healthy subjects and subjects with stroke.

Conclusion: Velocity threshold characterises the lengthening velocity at which muscle activity increases dramatically (Figure 1a) and was significantly lower ($p < 0.05$) in stroke subjects for soleus and medial gastrocnemius. Gain index represents the slope of the relationship between lengthening velocity and EMG activity. This parameter was used to characterise tibialis anterior and demonstrated differences approaching significance between groups. Both velocity threshold and gain index were shown to be valid criteria to quantify spasticity.

Introduction: Spasticity (stretech-reflex hyper excitability) in gait is characterised by the relationship between muscle lengthening velocity and EMG activity during periods of muscle lengthening. Previous studies have used gain index (referred to previously as spasticity index) to characterise this relationship [1,2]. However, these studies have calculated lengthening velocity from 2D kinematic data using muscle-tendon length rather than muscle length. The aim of this study was to derive the relationship between muscle lengthening velocity and EMG activity using full 3D kinematic data to calculate muscle fibre length. The relationship was investigated for three lower limb muscles: tibialis anterior, medial gastrocnemius and soleus to establish the suitability of the parameters velocity threshold and gain index for quantifying spasticity in each muscle.

Methods: Kinematic and EMG data was collected from 20 subjects with stoke and 16 sex and age matched controls whilst they walked along a 10 m walkway at a self selected speed. Full 3D ankle and knee joint kinematic curves were derived and used as input to SIMM modelling software which was used to obtain muscle length as a function of stance phase. This curve was differentiated to obtain muscle lengthening velocity. The raw EMG data was low pass filtered at 3Hz to produce a linear envelope and then normalised to maximum activity. Finally, lengthening velocity was plotted against normalised EMG activity (Figures 1a,b).

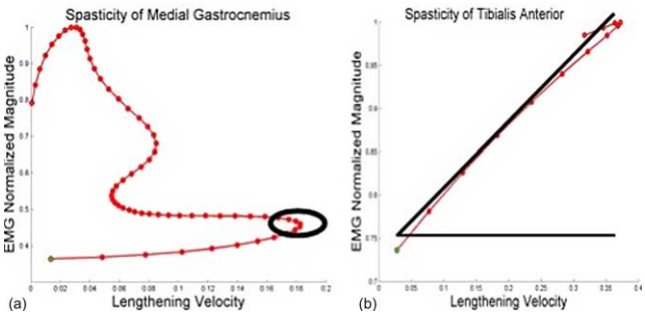

Figure 1. Spasticity.

Results: Two distinct patterns were found. Firstly in tibialis anterior (Figure 1b), there was a linear relationship between EMG activity and lengthening velocity. This slope of this linear relationship (gain index) was found to be higher for stroke subjects than controls and approached significance ($p = 0.065$). The second pattern, observed in medial gastrocnemius and soleus, was a counter clockwise loop in which muscle activity was seen to increase dramatically at a well-defined lengthening velocity. This velocity threshold was found to be lower in subjects with stroke than controls ($p < 0.05$) for both muscles. Both spasticity parameters were correlated to walking speed for the purpose of technique validation and showed moderate to strong correlations (0.52).

Discussion: The shape of the curve relating muscle lengthening velocity to EMG activity in gastrocnemius obtained in this study was found to be different from previously reported data [1,2]. This is most likely the result of using full 3D kinematic data to obtain muscle lengthening velocity. Although we found that spasticity in tibialis anterior could be quantified using gain index (as suggested previously), our study showed that velocity threshold was a more appropriate parameter for describing spasticity in soleus and medial gastrocnemius. Both spasticity parameters were shown to be valid criteria with which to quantify spasticity.

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O068

Inertial sensing improves clinical spasticity assessment

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Summary: A spasticity test, based on measuring the angle of catch, was evaluated in 20 children with cerebral palsy. Conventional post hoc goniometry was compared to concurrent measurement with inertial sensors.

Conclusions: A measurement of the angle of catch in m. hamstrings, m. gastrocnemius or m. soleus, in children with cerebral palsy, is much more precise when inertial sensors are used.

Introduction: The most common definition of spasticity is a motor disorder characterized by a velocity-dependent increase in muscle tone (i.e a "catch ") in response to fast passive stretch, resulting from hyperexcitability of the stretch reflex [1]. The angle at which the catch occurs, (i.e. the angle of catch, AOC), is reported as being a relevant measure of spasticity [2–4]. To assess the AOC, the joint needs to be repositioned, at the estimated AOC, and use a clinical goniometer to measure the joint angle. This study aimed to evaluate this procedure. As a reference, we used 3D inertial sensors that are developed for ambulatory measurements of orientation of human body segments [5].

Patients/Materials and Methods: Twenty children with a diagnosis of spastic CP participated in the study (6–17 years of age), GMFCS range [1–4] were measured 3 times. The AOC of the popliteal angle of the knee (hamstrings) was measured, as well as the dorsal/plantar flexion angle of the ankle at two knee angles (soleus and gastrocnemius). During the movement two lightweight inertial sensors, MT9 [Xsens, the Netherlands] tracked the motion of the proximal and the distal segment. From the inertial sensors signals, the angle at which the joint angular deceleration is maximal, gave the true AOC. Conventional clinical goniometry was performed after repositioning the joint with appropriately sized clinical goniometers, referred to as the posthoc AOC. The time instance of this static readout was marked at the inertial sensor signals, for additional comparison. Figure 1 shows a typical result for the poplitial angle, AOC is marked with an asterix, posthoc goniometry with a dot. Intra Class Correlations (ICC's) and Paired T-tests were used to compare the different goniometric modalities The error was defined as the absolute difference (i.e. AE: absolute error).

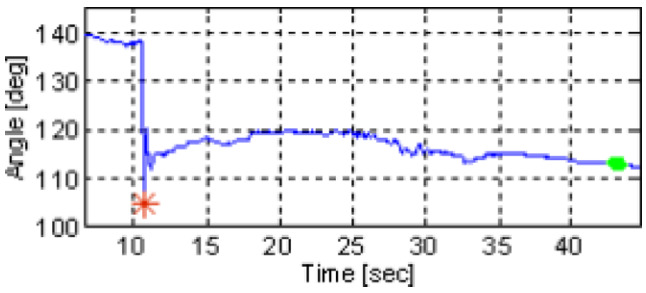

Figure 1.

Results: Not all muscles responded with a catch. The relation of posthoc AOC (by conventional goniometry) to the true AOC; is shown in the table below. Only the AOC of the gastrocnemius was significantly different ($p < 0.05$).

Posthoc goniometric AOC versus	N	ICC	Difference (Mean±SD)	Mean AE
true AOC Hamstrings	36	0.55	0.3±14°	11°
true AOC Soleus	43	0.67	−1.3±7.3°	5.8°
true AOC Gastrocnemius	43	0.36	3.7±8.3°	6.8°

Discussion: Preliminary concurrent optoelectronic measurements confirmed that our inertial sensor setup is accurate within 1 degree. The results show that for the whole group only for the m. gastrocnemius a small systematic difference is found. However random errors between posthoc goniometry and true AOC are quite considerable, as expressed by the low ICC and high mean absolute errors. The additional analyses revealed that main part of this error resulted from erroneous repositioning, while a lesser part is due to misalignment of the goniometer. Instrumented assessment of spasticity (with inertial sensors) means an important improvement of this clinical measure, i.e within the range that is considered acceptable in clinical movement analysis. Whether this improved precision is serving its ultimate aim, a better clinical decision making, is subject to future research.

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