A study of the biomechanics and kinematics of standing
Phase 1, developing the methodology

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Introduction
This project has arisen from discussions with other healthcare professionals about the most appropriate standing support. Several different standing supports are currently routinely used including the Chailey Standing Support and it is not known which standing support provides the most appropriate position. The methods and techniques used in this study are routinely used in gait analysis but are being used in a different application.

Standing supports are routinely prescribed for children with physical disabilities however there is limited scientific evidence for their use. Their provision and use are based on the health professionals own experience and their clinical practice.

The posture that is achieved in a standing support depends not only on the ability of the child but also on the postural control offered by the support. There is currently no evidence that provides guidance on the most effective posture that should be achieved within supported standing. Nor is there evidence for the movement achievable for the best outcome. Furthermore there are currently no quantitative measures of typical standing on which to base recommendations for children with cerebral palsy. This project will begin the process to providing evidence to inform the use of standing supports.

Children with physical disabilities often use a wide range of equipment which can be expensive. Currently equipment is not provided in a systematic way and there are no consistent assessment and provision criteria. Equipment is generally provided on a piece by piece basis and it can be difficult to find funding for it. Standing supports cost in the region of £1000. It is therefore important to have evidence to support the use of such equipment.

The aim of this study is to define the parameters for standing support provision. This will be achieved by studying the early development of standing ability and comparing this to standing and supported standing for children with cerebral palsy.

Hypotheses
There will be a recognisable pattern of biomechanical and kinematic activity during set tasks in typically developing children in standing.
This pattern will be different for typically developing pre/early walking children and children with cerebral palsy.
The pattern for typically developing children can be replicated in supported standing.

Background
As a typically developing child reaches the end of their first year they begin to pull up, stand and experience their environment from a vertical position. Ninety percent of typically developing children are able to achieve this by 10 months (Piper and Darrah 1994). For those who cannot stand independently such as some children with cerebral palsy, standing supports may be used. As well as being used at this early developmental stage standing supports are used by other people with disabilities across all age groups and types of disabilities. From the literature, the reported reasons for using such supports for this wide group are varied and include weight bearing, muscle stretch, feelings of wellbeing, improved circulatory, renal and bowel function (Eng, M et al. 2001)

(Gudjonsdottir and Mercer 1997) (Stuberg 1992) (Tremblay 1990) (Walter, Sola et al. 1999) (Wilmshurst, Ward et al. 1996). Although there is much discussion of the benefits of standing supports the evidence is very limited.

At Chailey Heritage Clinical Services research has been carried out to investigate the early stages of motor development (Pountney, Mulcahy et al. 2000). The Chailey levels of ability provide an observational measurement scale. The postures that were investigated were lying in prone and supine, sitting on the floor and on a support and standing. The levels were originally developed from typically developing children and then validated for children with cerebral palsy. The typical development model was adopted to promote development, increase function and to reduce the progression of deformity. Following the research on the levels of ability, equipment has been developed to enable children with a low level of ability to experience a higher level of ability, one such piece of equipment is the Chailey Standing Support (Green, Mulcahy et al. 1993). A recent study (Pountney, Mandy et al. 2002) found that children using the Chailey postural management programme, which includes the standing support, before hip subluxation were significantly more likely to maintain hip integrity than children using other positioning equipment or not using any.

The standing support has been successfully used by children at Chailey Heritage School and outpatients attending Chailey Heritage Clinical Services for over ten years. Observationally the Chailey standing support is able to improve the standing posture of the children using it but it is not known if the biomechanics of the users are altered to closer replicate that of a typically developing child.

Research has indicated that biomechanics, more specifically joint position, has an impact on muscle activity(Woollacott and Burtner 1996) (Burtner, Qualls et al. 1998). The studies found that standing typically developing children in a crouch gait posture elicited the same responses to perturbations as children with cerebral palsy. It is hypothesised that altering biomechanics may influence patterns of muscle activity and therefore if typical positions are simulated then typical responses may be elicited.

In gait analysis there are well researched patterns of biomechanics and kinematics to describe the muscle activity, movement of the body and limbs and forces that are produced (Campbell, Vander Linden et al. 1994). It is thought that there will also be similar patterns for standing whilst conducting a set of standard tasks.

Plan for the investigation

The study has three phases. The first phase being reported in this paper will be used to help inform and develop the methodology. The second phase will be used to collect control data from typically developing children and investigate if there is a recognisable pattern of muscle activity and joint position. The third phase will be used to collect data from children with cerebral palsy and find out how they differ from the pattern obtained from typically developing children and if the pattern can be altered in supported standing.

Methodology for Phase 1

Equipment

1. The trial equipment for subjects to stand in consisted of a Chailey Standing Support size 4 and plinth with standing support tray at elbow level. The tray had 5 positions marked on it for the activities.

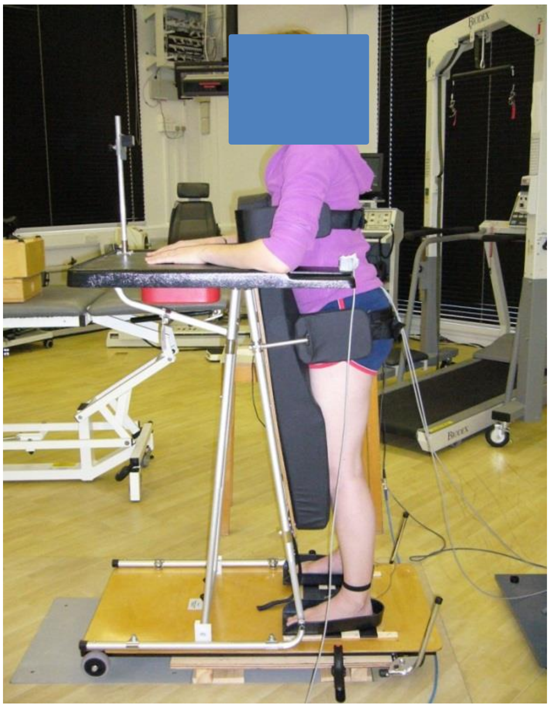
2. Biometrics Datalink to collect muscle activity data (sampled at 1000 Hz) using surface electrodes and elbow movement from an electrogoniometer (sampled at 50Hz).

3. AMTI Force plates to collect centre of pressure data.

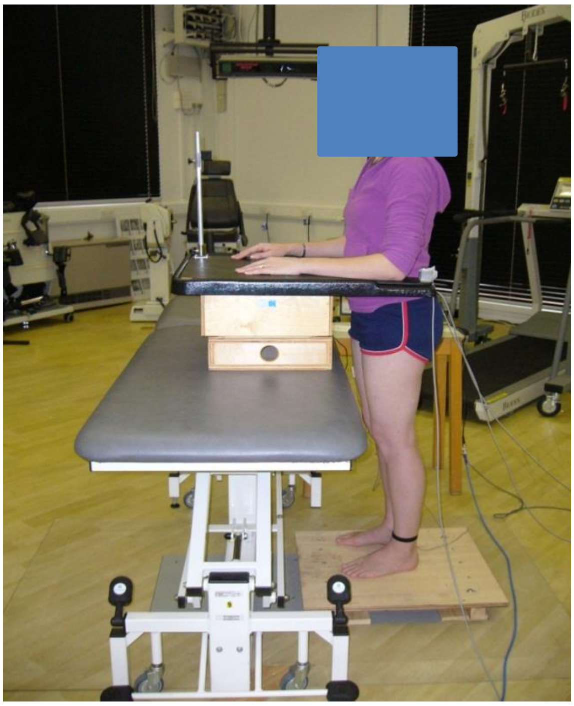
4. The Fastrack system was used to capture motion. Data was collected from 3 sensors (one on the pelvis, one on the spine and one on the standing support tray.

5. The equipment was linked using a modified electrogoniometer. When the force plates and motion analysis systems started then a marker was placed on the emg trace

Photographs of the set up were taken and an example of this can be seen below.



Standing in the Chailey Standing Support



Standing by the plinth with the tray at elbow height

Method
Eleven healthy, adult, subjects were recruited to the study. Each subject was assigned a subject number. Basic body measurements were taken to enable standing support and the plinth to be set up for each subject. The height from the footplate to the tray was measured and recorded.

Data was collected from the right hand side of the body. The electrodes were placed on the medial head of gastrocnemius, the quadriceps, the rectus femoris and the main belly of hamstrings.

The subjects were asked to complete a set of activities, with the position marked on the tray, as follows:

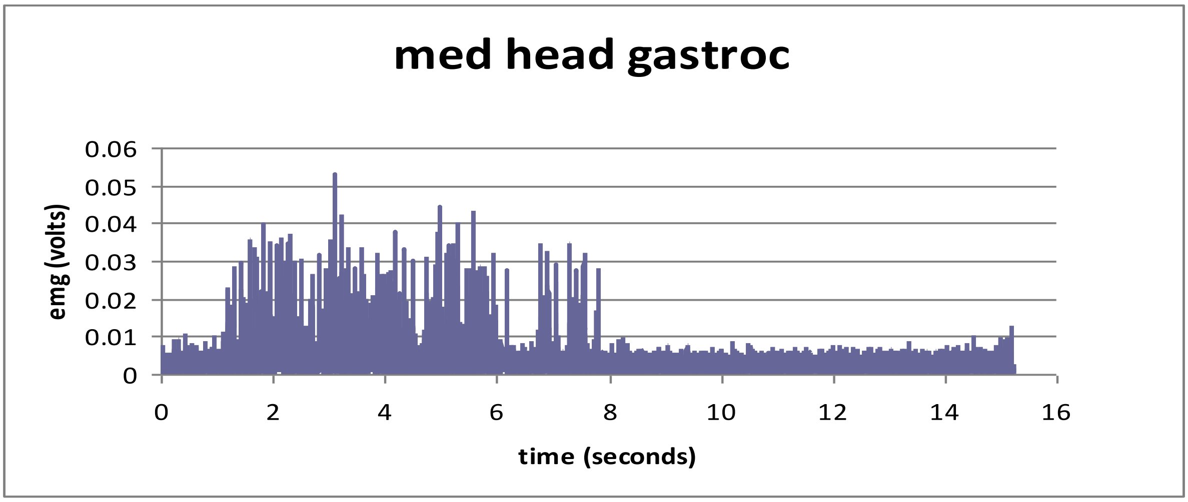
1. Hand at rest on the tray
2. Hand to touch centre of tray (and back to rest position)
3. Hand to touch left hand front corner of tray (and back to rest position)
4. Hand to touch point at shoulder level, forwards level with front of tray
5. Back to rest position

The test was repeated up to 5 times in each set up
The subjects were measured in first in and then out of the standing support.

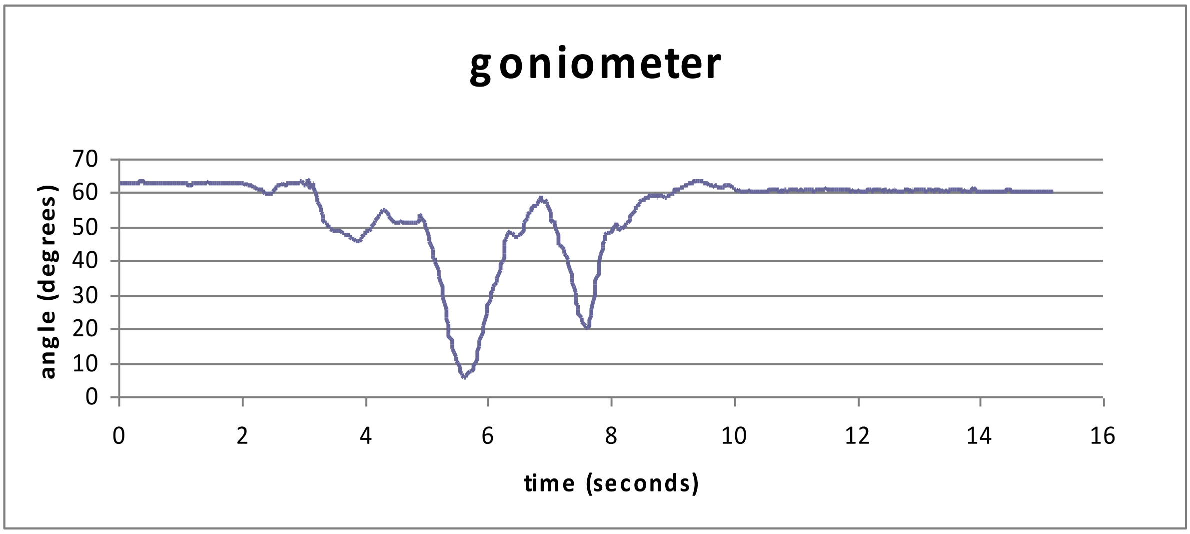
Results
Twelve sets of data were collected from 11 subjects. For one subject a second set of data was collected for subject comparison. The preliminary results are described below.

The muscle activity data was exported from Datalink and processed using Matlab to filter (low pass, high pass and for noise), full wave rectify, detrend and convert to volts. The goniometer data was converted into degrees.

The graphs below (graph 1 and graph 2) show subject 1 in the standing support. The top graphs shows the muscle activity of the medial head of the right gastrocnemius across the set of activities and the lower graph shows the change in elbow angle during the same time period. Form observation it can be seen that the muscle activity takes place during the activities but reduces during the quiet or still standing time.

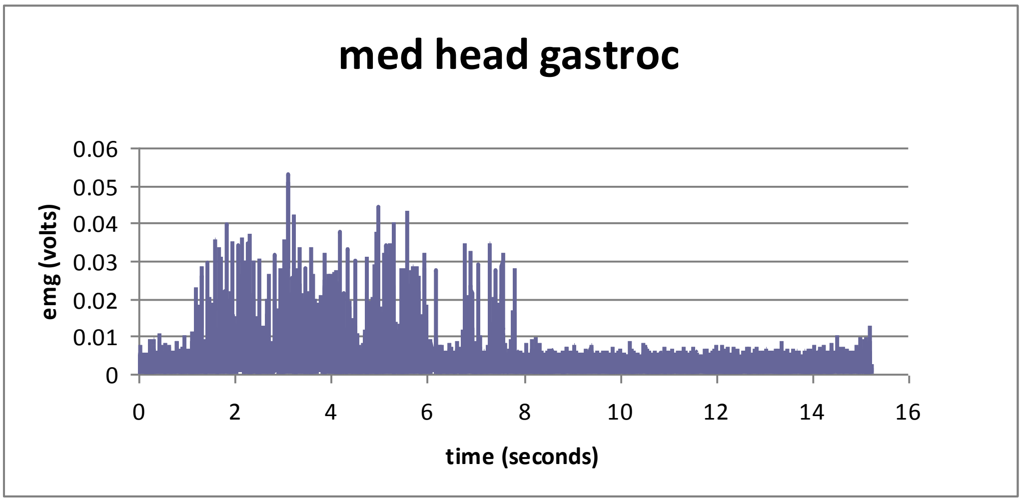


Graph 1- muscle activity

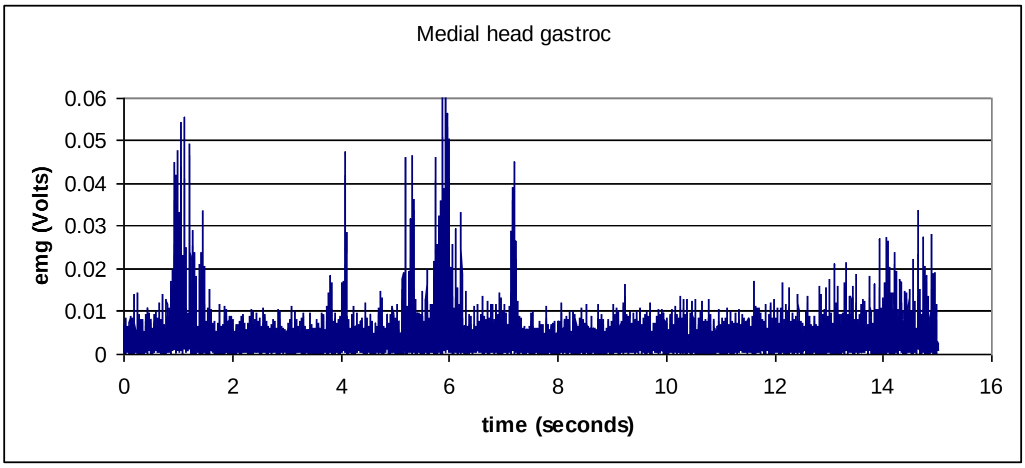


Graph 2- elbow angle

The graphs below (3 and 4) show the muscle activity of the medial head of the gastrocnemius of subject 1 in and out of the standing support. From the graphs it can be seen that the muscle activity is of a similar maximum value in and out of the standing support but that the duration of the muscle activity is longer out of the standing support.



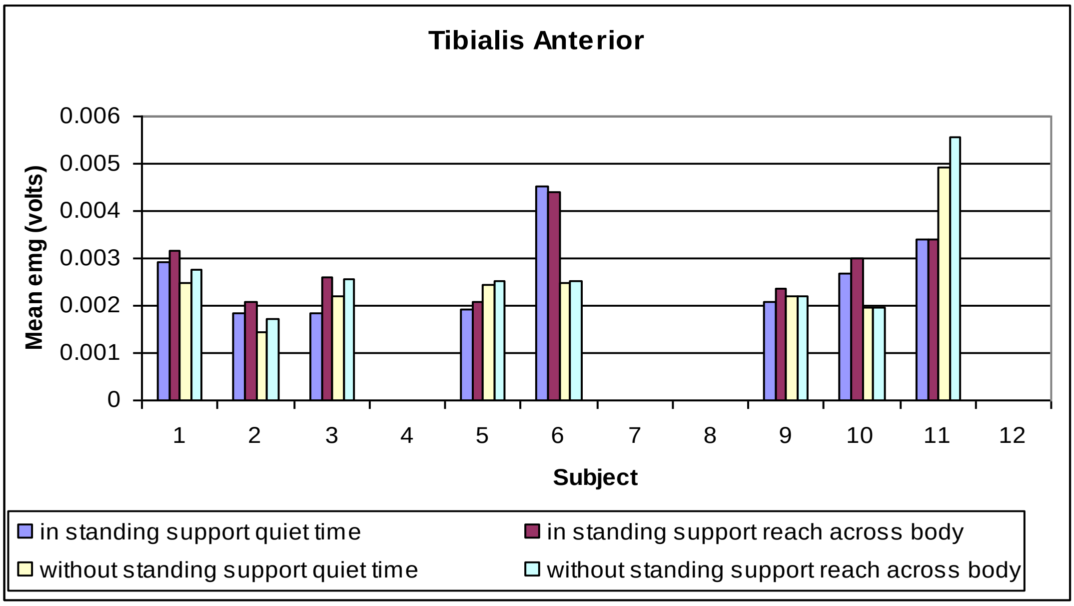
Graph 3- muscle activity in standing support



Graph 4- muscle activity out of standing support

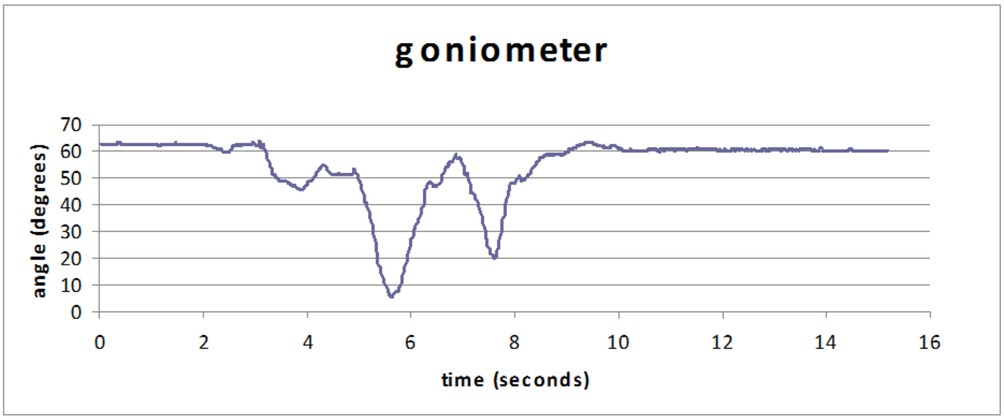
Graph 5 below shows the mean muscle activity during quiet standing and the activity of reaching across the body, and described in the methodology as touching the left front corner of the tray with the right hand then returning to the rest position. The data for subjects 4, 7, 8, and 12 have been removed as there were some outliers.

From the graph it can be seen that as expected for most of the subjects there was a greater amount of muscle activity during the activity as opposed to the quiet time. The muscle activity was approximately the same or less out of the standing support for all but one of the participants.

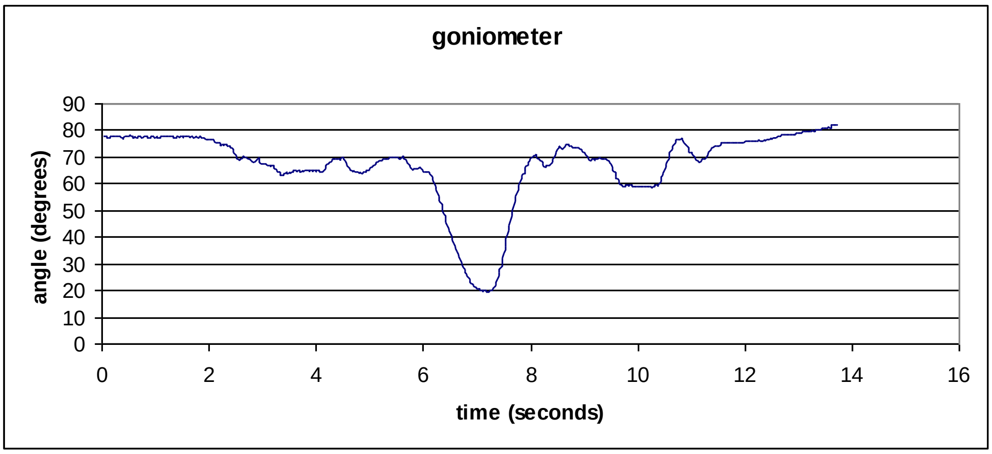


Graph 5- Mean emg

The graphs below (graph 6 and 7) show the kinematic variability between the subject 1 and 6. There is a variation in the time it takes to carry out the activities 10 seconds for subject 1 and 12 seconds for subject 2. There is also a variation in the amount and speed of the elbow flexion and extension.

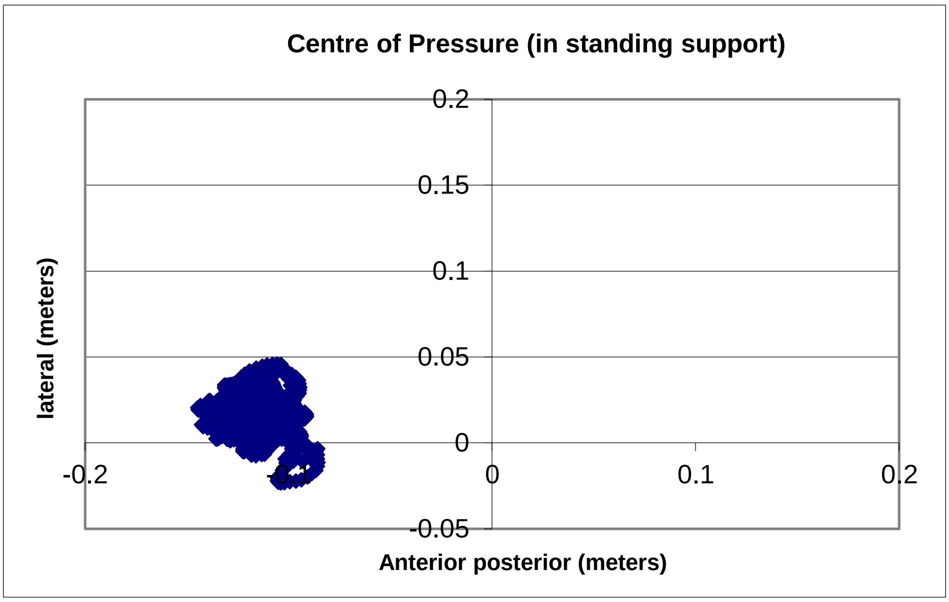


Graph 6- elbow flexion in degrees, subject 1

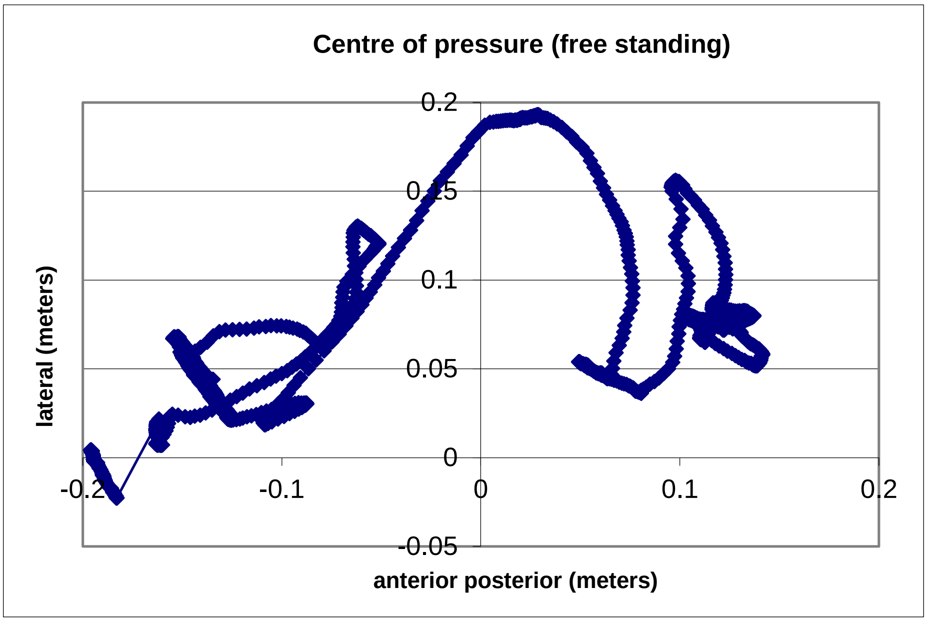


Graph 7- elbow flexion- subject 6

Graph 8 and 9 demonstrate the how the centre of pressure moves during the set of activities. From the graph it can be seen that in the standing support the centre of pressure covers a smaller area than out of the standing support.



Graph 8



Graph 9

Discussion

This study used a group of healthy adults to gather baseline information. From the photographs of the subject in and out of the standing support it can be observed that the standing positions are different. The standing support places the subject in a developmental position with weight forward over their base whereas in a free standing position the subject stands more upright. The standing support position is based on a typical development position of early standing. The adults will have passed through this stage and therefore encouraging them to stand in an early standing position may elicit results particularly for muscle activity that are not as expected. Different subjects may respond to this standing support position in different ways hence the results indicating that some use greater and some less muscle activity in the standing support. It is possible that the results may be more consistent for prewalking children and for children with cerebral palsy that do not walk independently and are at the developmental stage of standing supported by the standing support.

Muscle Activity

From the graphs (1 and 2) the muscle activity of the medial head of the gastrocnemius can be seen to be activating when the angle of the goniometer changes. This angle change represents the movement of the arm through the set of activities. This result is as expected as movement of the upper limbs may cause a change in postural muscles in the lower limbs to compensate for the position of the arm.

When the muscle activity of the medial head of the gastrocnemius is compared in and out of the standing support for this subject it can be seen that there is greater muscle activity in the standing support rather than out of it. The peak voltage, maximum contraction, is similar but the amount of time the muscles is activating is longer in the standing support. This may be due to the subject trying to compensate for the position that they are being held in by the standing support.

Mean muscle activity

From graph 5 the variation in mean muscle activity in the tibialis anterior can be seen during the reach across the body task both in and out of the standing support. As discussed earlier the subject differences may be in the individuals response to being constrained in the standing support position in that some may 'fight' against it while others may 'relax' into it.

Subject Variability

The goniometer activity in graphs 6 and 7 shows the subject variability between two subjects. Although the shape of the pattern is the same for both clients the time taken to do the task and the amount of movement varies. This is as expected.

Centre of pressure

The final two graphs (8 and 9) show the centre of pressure in and out of the standing support for one of the subjects. The graphs have the same scales and it can be seen that the centre of pressure covers a smaller area in the standing support. From the restrictions to the body position that a standing support places on the subject it would follow that the centre of pressure would be over a smaller area in rather than out of the standing support.

Conclusions and further work

The results presented in this paper form the preliminary findings from the data analysed to date. As further analysis is required it is not yet clear if there is a recognisable pattern of biomechanic and kinematic activity during set tasks in standing but the results to date are encouraging.

The next stage is to complete the analysis and test the reliability. The other hypotheses for typically developing children and children with cerebral palsy then need to be tested and then the findings need to be put into practice.

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