A Protocol for 3D kinematics and electromyographic analysis of the upper limb applicable to cerebral palsy children

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***Abstract*— Upper limb involvement in cerebral palsy is usually more complex than in lower limb and current clinical evaluation methods do not fully assess the function of upper limbs during simple activities of daily life for cerebral palsy patients. We thus defined a protocol allowing the 3D kinematics and EMG analysis of upper limbs during defined tasks in order to complete the clinical analysis of such patients. The first data were obtained for intact or pathologic subjects and reproducibility tests are in progress.**

Keywords- upper limb; 3D kinematics; EMG; cerebral palsy.

I. INTRODUCTION

The cerebral motor infirmity is a pathology that generally induces an impairing of walking and of the upper arm function. Gait analysis for such patients has been very useful for better understanding walking physiopathology and to improve treatments. Current clinical methods of assessment do not fully evaluate the kinematics and EMG activity of the upper limb during simple activities of daily life. Usually, upper limb evaluation is made in terms of function, motor control, dexterity, tone and degree of fixed versus dynamic deformity. Moreover, planar measurements of passive and active articular ranges of motion are performed. These static single plane measurements assess incompletely the ability of the child to perform daily activities. The 3D kinematics analysis using external non invasive markers, commonly used on the lower limbs are now starting to be used on the upper limbs, with some specific difficulties, such as the greater complexity of the upper limb and the non cyclic aspect of its daily use. The aims of this study are then to define a protocol to analyse the 3D kinematics and the EMG activity of the upper limb in order to complete the clinical analysis of such patients and to obtain a quantified evaluation before and after treatment.

II. MATERIAL AND METHOD

Two simple daily tasks were defined whose aim was to put in movement the different segments in various directions, the subject being sitting on a chair, with the hips and the knees flexed at 90°. During the first task (cookie test) the subject begins the task with the hand on his knee (analysed side), then he takes an object on a table placed in front of him, then he put the object to his mouth, then he brings back the object and comes back to his initial position. For the second task (displacement task), the subject begins the task like previously, then he takes an object placed on a table in front of his knee (analysed side), he displaces the object on the table in front of his opposite knee, he comes back to his initial position, he takes the object and replaces it to its first position and he comes back to his initial position. Each task was repeated three times in order to assess the reproducibility of the movement.

A VICON optoelectronic system with six cameras was used for kinematics measurements. The three-dimensional kinematics analysis of the upper limbs was based on rigid segment approach in which each segment is assigned to one bone. Four segments (trunk, arm, forearm, hand) were analysed for which anatomical frames were defined. For the trunk, the anatomical referential was defined using the two sterno-clavicular joints and the xyphoid process. For the arm, the anatomical referential system was defined using markers placed on the medial epicondyle, on the lateral epicondyle and on the acromion. For the forearm, the anatomical referential system was defined using markers placed on the medial epicondyle, on the lateral epicondyle, on the radial and ulnar styloïds. For the hand, it was defined using the two styloïds, the second metacarpus and the fourth metacarpus.

In order to avoid any displacement between markers of the same segment during movements and to limit errors due to the movement of the markers on the skin, rigid tripods on which three markers were fixed were used during movements. These tripods were fixed using a strap on the distal and dorsal part of the forearm, on the dorsal part of the hand and on the sternum while using an elbow-guard on the distal and external part of the arm (figure 1).

An initial static calibration phase, at rest position, was required in order to determine the relative position of referential frames associated with the rigid tripods in relation to the anatomical frames obtained from skin markers. Then, the anatomical markers were removed leaving only the rigid tripods.

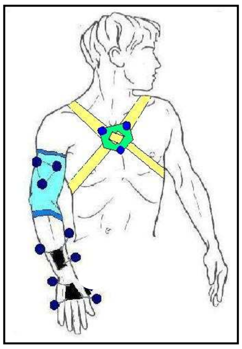

Figure 1. Position of the tripods

Finally, the following angular motions were calculated for each task using the transformation matrix between the anatomical referential systems of the two segments, which have been interpreted as a combination of three successive rotations of the proximal segment relatively to the distal one, according to a defined mobile axes sequence: Arm / trunk (called “shoulder”): flexion-extension, abduction-adduction and internal-external rotation; Forearm / arm (elbow): elbow flexion-extension (rotation around an axis connecting the two epicondyles) and forearm pronation-supination (rotation around an axis connecting elbow and wrist centers); Hand/forearm (wrist): flexion-extension and radial-ulnar inclination.

Surface electrodes were fixed on 11 muscles or muscular groups and connected to the VICON workstation, in order to get simultaneously the electromyographic activity of these muscles and the kinematics of the upper limb. The included muscular groups were: anterior deltoid, middle deltoid, posterior deltoid, biceps brachii, triceps, extensor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, pectoralis major, pronator teres). In some cases, due to the small size of the limb, it was not possible to fix all the electrodes.

As the movements were carried out at different speeds from one trial to another, a normalisation (duration from 0 to 100%) of the curves was necessary in order to allow a comparative study within and between the sessions of one patient and also between patients.

An analysis of the repeatability was carried out using the Coefficient of multi correlation (CMC), calculated for the three repetitions of the task. For the two depicted tasks and for each angle, the mean standard deviation and the CMC were calculated.

The first tests were performed on both healthy and hemiplegic subjects. Intra-session and inter-session (removal of tripods between sessions) comparisons are in progress.

III. RESULTS

The figure 2 is an illustration of the normalised curves (three trials and mean curve) of elbow flexion extension angle during the cookie test, with mean Standard Deviation and global CMC.

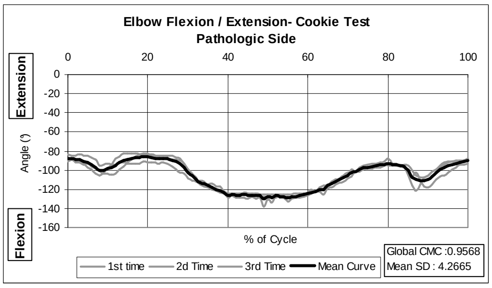

Figure 2. Reproducibility of elbow flexion-extension during cookie test: three trials and mean curve, global CMC and mean standard deviation.

When comparing the three repetitions of the tasks during the same session, the global CMC was higher than 0.84 in 80% of cases. When comparing four different sessions for the same subject, the CMCs were always higher than 0.84 except for the shoulder axial rotation during the cookie test (0.82) and for the wrist radial-ulnar inclination during cookie test (0.68) and during displacement task (0.78).

The figure 3 gives comparative data between the intact side and the pathologic side of the same subject, indicating an alteration of the kinematics pattern. The same kind of data was obtained before and after treatment for one subject, quantifying the effect of this treatment.

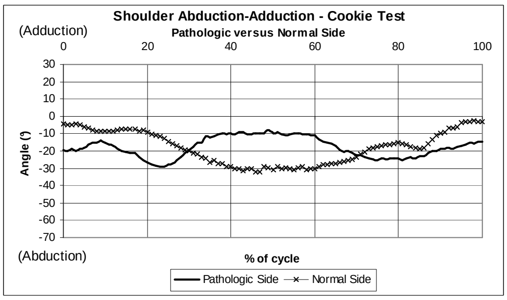

Figure 3. Shoulder abduction-adduction during cookie task for hemiplegic and normal sides of a pathologic subject

Another interest of our protocol is to provide combined kinematics analysis and EMG data (figure 4).

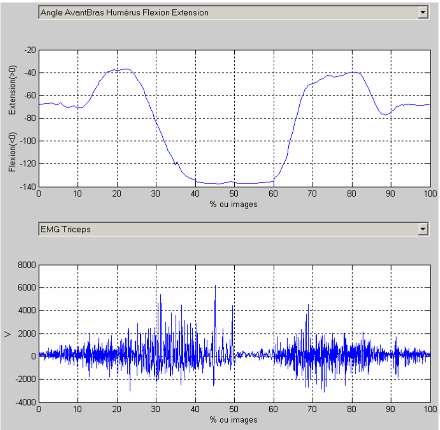

Figure 4. EMG Signal of the Biceps in paralell with elbow flexion-extension during displacement task.

IV. DISCUSSION AND CONCLUSION

We defined in this study a protocol allowing the quantification of upper limb function (kinematics and EMG) during to simple daily tasks, which could be performed by both healthy and pathologic subjects. The first results show correct reproducibility and uniformity in strategies adopted by a given subject. Moreover, differences could be shown up between healthy, pathologic and post-treatment situations. Nevertheless, a study on a greatest number of patients and further reproducibility tests are still necessary and are in progress to confirm our first results. Moreover, it could certainly be interesting to perform accuracy tests assessing the error due to the potential movement of the tripod relative to bone due to the sliding of the skin.

After the completion of the reproducibility tests, such a upper limb motion analysis protocol can be a useful tool for evaluation before and after treatment of patients with neurologic disorders and we hope that it will be a help for the clinicians in the treatment of these pathologies.

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