A NEW PROTOCOL FOR UPPER LIMB CLINICAL WALKER-ASSISTED GAIT ANALYSIS

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SUMMARY

In clinical gait labs it is not uncommon to evaluate patients forced to walk with various walking aids such as anterior and posterior walkers, but the analysis is generally restricted to the lower limbs only. This study aimed at developing a novel inverse dynamics protocol to study trunk and upper limb kinematics and kinetics during walker-assisted gait by using load cells easily fixable and adaptable to the subject's own walker. The most appropriate coordinate system to be used for representing joint reaction forces and moments in an anatomically consistent way is also discussed. Future integration of this model with a traditional lower limbs model will allow full-body kinematic and kinetic gait analysis.

INTRODUCTION

An instrumental clinical gait evaluation is mainly based on kinematic, kinetic and electromyographic measures. In clinical gait labs it is not uncommon to evaluate patients forced to walk with walking aids such as anterior and posterior walkers.
Upper Limb (UL) kinetics during locomotion with walking aids was already studied [1,2], but the load cells used during those trials were not suitable for daily clinical routine as they are rigidly fixed to a particular walker.
The use of two load cells that can be easily assembled and adapted to a wider range of different walkers would allow the measurement of bilateral three-dimensional forces and moments applied by the subject on his own walker [3].
An inverse dynamics model is therefore proposed for the quantification of bilateral loads at shoulder, elbow and wrist.
Since the choice of the coordinate systems to use for the computation of the three force and moment components at the joints will affect the final result, the coordinate axes orientation needs to be consistent with the joint functional rotation axes.

METHODS

An adult anterior walker (Fig.1) was instrumented with two 6 DOF multi-axis load cells to measure loads exerted by the hands on the walker. Cell signals were amplified and acquired synchronously with kinematic data via a 12 cameras Vicon MX system (OxfordMetrics, Oxford, UK) equipped with Nexus 1.5 software.
The Upper Limbs (UL) model consists of the trunk, upper arms, forearms and hands. The term trunk is used to define the thoracic segment. Body segments were defined using 20 reflective markers plus five markers on each one of the two load cells fixed on the walker. Markers for the trunk were placed on T2, T6, T12 and sternal notch following the Oxford Trunk Model [4]. Upper arm was defined by markers placed on the acromion process (acromion-clavicular joint) plus two additional markers placed anteriorly and posteriorly on the shoulder for static calibration of the gleno-humeral joint centre (GH), on medial and lateral humeral epicondyles. The last two markers were also used to define the forearm segment together with markers at the ulnar and radial styloid processes. The hand was defined by markers at the ulnar and radial styloid processes and 3rd metarsal.
Vicon BodyBuilder 3.6 software was used to develop the kinematic and inverse dynamics model.
Coordinate systems were defined following the ISB guidelines [5]. With arm lying along the trunk, elbow straight and hand palm facing forward, for every segment the X-axis is anteriorly directed, the longitudinal Y-axis is superiorly directed and the Z-axis is directed laterally following a right-handed convention.
GH joint centre was computed as the centre of a circle encompassing the 3 shoulder markers. Elbow joint centre was placed at the mean point between the two humeral epicondyles. Wrist joint centre was defined coincident with the ulnar styloid [5].
Rotations were described using Cardan-Euler Z-X-Y (flexion-extension, ab-adduction, internal-external rotation) sequences.
Anthropometric data for the inverse dynamics computations were taken from [6], with a slight adaptation for the hand, considering that is is holding the handle.
Data shown here are relative to one subject (27 years, 1.69 m, 62 Kg), who was asked to walk by loading the walker at approximately the 60% of the body weight when stepping forward. The first step after placing forward the walker had always been done with the left foot, with an asymmetrical movement. Handles were placed at 60% of subject's height.

Figure 1. Instrumented handles fixed on an anterior walker

RESULTS AND DISCUSSION

Joint moments at the shoulders, elbows and wrists are shown (Fig. 2) for left and right gait cycles from heel-strike to heel-strike. Final data were filtered (Vicon Woltring filtering routine, GCV option) before output. Graphs are time normalized to 100% gait cycle. Values for the moments are normalized by the subject's body mass and expressed in Nm/Kg. The three moment components (flexion-extension, ab-adduction, internal-external rotation) are expressed as internal moments in the coordinate system of the proximal segment connecting to that joint. This choice allows to show data that are more significant with respect to the functional anatomy of the considered joint and more intuitively relatable to muscles function. However, a graph representing the internal-external moment at the shoulder joint expressed in the humerus coordinate system is added, because it seems useful to have the possibility to evidence the torsional action from both the trunk and the shoulder point of view.

Asymmetry of the curves relative to the two sides is related to the walking strategy. Results seem consistent with findings published in [1], considering the differences in walking conditions, gait cycle and moments computation.

CONCLUSIONS

A novel UL inverse dynamics model for upper limbs kinetic assessment during walker-assisted locomotion is proposed, together with an anatomically consistent convention for joint reaction forces and moments representation.

The model, based on measures from load cells easily adaptable to different walker models, can be used for research purposes and clinical assessment and may help in investigating the best patient's position on the walker as well as testing new walker models.

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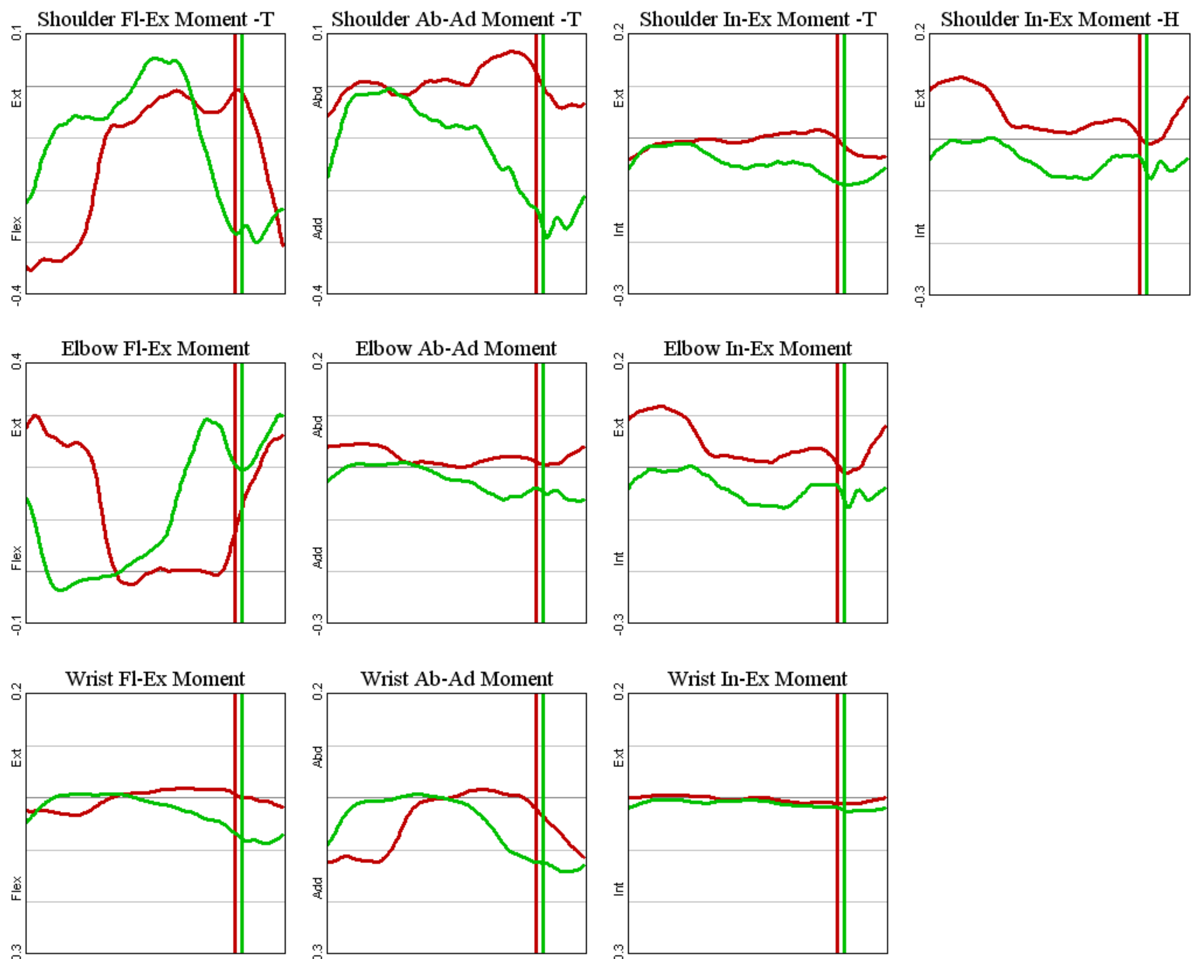

Figure 2: Joint reaction internal moments for the right (green) and left (red) sides for a healthy subject during a gait cycle. Shoulder axial rotation moments are expressed in both trunk (-T) and humerus (-H) coordinate systems.