An investigation of 3D torso model to monitor compensatory movement in stroke patients during cross-body reaching assessment

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ABSTRACT – Compensatory movements are often utilized by stroke patients to augment the loss of motor function in completing their daily activities. This paper presents the investigation of 3D torso model to monitor torso compensation using minimal motion capture setup. The belt marker model is used, and the markers were monitored only by a minimal 3 IR camera setup. Two subjects performed cross-body reaching assessment in normal and simulated stroke setup. Their hand and torso movements were recorded and analyzed. Substantial differences were observed in lateral flexion compensation for both subjects, while small differences were also observed in forward flexion compensation. The belt marker model has the potential to be used in minimal setup to observe compensatory movements in stroke patients.

1. INTRODUCTION

Cross body reaching is one of the assessment items that are widely used internationally to observe the improvement in motor functions after stroke [1]. People who suffer from stroke typically has substantial torso movements to overcome the absence of distal voluntary function when performing tasks of daily living in comparison to a healthy individual.

Motor compensation in trunk includes the utilization of torso, scapular as well as shoulder abduction and internal rotation. Existing research has used only sternum marker to observe torso movement, which only explains the displacement of sternum in one dimension in comparison to the possible three-dimensional torso movement [2].

Three-dimensional (3D) movements are commonly monitored by a 3D motion analyser in biomechanical research. However, the setup is expensive as markers are required to be observed with multiple cameras setup to be viable for analysis. One of the most applied optoelectronic motion capture system is Vicon which has its own "Conventional Gait Model" but require at least 6-cameras setup to be feasible for analysis.

Since most upper limb assessment activities are performed seated and require much lesser movement than other sport activities, we propose the use of a belt model monitored by only 3-cameras setup to monitor a 3D movement of the torso when performing cross-body reaching.

2. METHODOLOGY

Two male subjects were asked to perform a cross-reaching body task while seated in a chair without back support and wheels. Markers are placed according to Figure 1. Markers for arm and hand are only used to ensure activities are completed as intended and were not utilized for this research. Only upper belt markers are used in this research as the lower belt markers suffer discontinuity during motion capture. Subjects are seated within the capture volume of three VICON cameras, the minimum setup to determine 3D kinematics.

Figure 1 Marker placements for arm and hand movement (left) and torso movement (right)

The trunk was stabilized by sitting comfortably with a correct posture guided by the author. The shoulder was in approximately 0° flexion and extension 0° of internal rotation and elbow is in 75° to 90°, flexion with the wrist rested palm down and the finger joints in slight flexion positioned on the knees. The subjects were required to touch the contralateral earlobe with their right hand.

Subjects were given few practice trials prior to familiarize themselves with the task pattern and instruction, respectively for normal and simulated stroke. Data collection was limited to ten trials to reduce the fatigue. Simulated stroke setup was performed using an elbow brace to simulate the limited arm-forearm coordination typically suffered by stroke patients.

2.1 *Torso angle determination*

Each marker is labelled as X_1, X_2, X_3, X_4. The X_T-, Y_T- and Z_T-axis of the torso were computed as represented in Equation (1)-(3):

$$Y = \frac{X_1 - X_2}{|X_1 - X_2|} \quad (1)$$

$$Z = \frac{Z_1 - Z_2}{|Z_1 - Z_2|} \quad (2)$$

$$X = Y \times Z \quad (3)$$

The torso angles are determined by computing the relative movement of torso coordinate system in comparison to global coordinate system. The coordinates of each axes were organized column-wise in 3-by-3 matrix [**X**, **Y**, **Z**] which served as the rotation matrix, R of the torso coordinate system with respect to global coordinate system as shown in Equation (4). Lateral flexion rotation angle, β, axial rotation angle, γ and forward flexion rotation angle, α are then computed represented in Equation (5)-(7). These computations are further elaborated in [3].

$$R = \begin{bmatrix} R_{0,0} & R_{0,1} & R_{0,3} \\ R_{1,0} & R_{1,1} & R_{1,3} \\ R_{2,0} & R_{1,2} & R_{2,3} \end{bmatrix} \quad (4)$$

$$\beta = cos^{-1}(R_{1,3}) \quad (5)$$

$$\gamma = tan^{-1}\left(\frac{R_{0,2}}{R_{2,2}}\right) \quad (6)$$

$$\alpha = tan^{-1}\left(\frac{R_{1,1}}{R_{1,0}}\right) \quad (7)$$

3. RESULTS & DISCUSSION

The mean torso angle differences for lateral flexion, axial rotation and forward flexion between repetitions only exhibits minor differences as tabulated in Table 1. These results were expected since the inter-joint coordination were intact in healthy person in comparison to hemiplegic stroke patients [4].

Table 1 Mean torso Angle Differences in normal setting

Torso angle	Subject 1	Subject 2
Lateral flexion	1.01°	0.17°
Axial rotation	0.62°	0.18°
Forward flexion	0.13°	0.13°

However, the torso angle plot for normal movement versus simulated stroke presents quite a substantial mean difference. As shown in Figure 2, the mean difference between normal and simulated stroke exhibited by subject 1 for lateral flexion was considerably high at 15.67° although axial rotation and forward flexion was quite small at 2.45° and 0.44° respectively.

Similar result was exhibited by subject 1 in which lateral flexion differences was recorded at 10.38° which is considerably larger than axial rotation at 0.28° and forward flexion at 1.09°. This observation supported previous research that concluded the use of compensatory torso movements by stroke patients to aid the arm transport when performing cross body tasks [3].

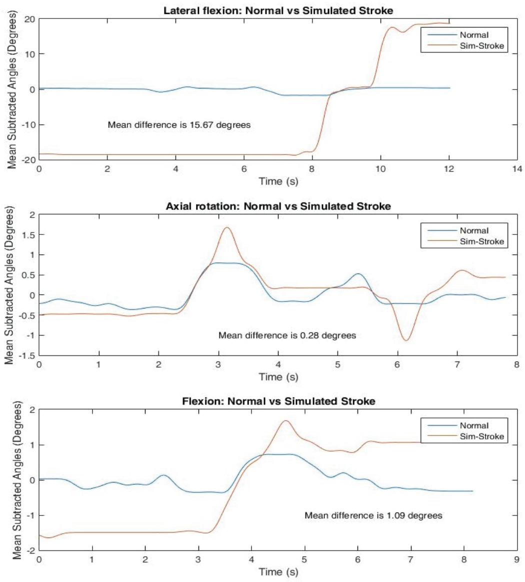

Figure 2 The torso angle plot for normal vs. simulated stroke condition for Subject 2

4. CONCLUSION

The use of a simple belt model was able to capture the compensatory torso movement as evident from previous research with the minimum 3D motion capture setup. Further investigation will be conducted to discover whether this minimum setup is feasible to be used for planar tracing tasks which are also integral in stroke assessment with robot-assisted rehabilitation.

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REFERENCES

[1] Alt Murphy, M., & Häger, C. K., Kinematic analysis of the upper extremity after stroke – how far have we reached and what have we grasped?, *Physical Therapy Reviews*, vol. 20, no. 3, pp. 137–155, 2015.

[2]Mandon, L., Boudarham, J., Robertson, J., Bensmail, D., Roche, N., & Roby-Brami, A. , Faster Reaching in Chronic Spastic Stroke Patients Comes at the Expense of Arm-Trunk Coordination, *Neurorehabilitation and Neural Repair*, vol. 30, no. 3, pp. 209-220, 2015.

[3] Nordin, N., Xie, S.-Q., & Wunsche, B., *Simple torso model for upper limb compensatory assessment after stroke. 2016 IEEE International Conference on Advanced Intelligent Mechatronics (AIM)*, 2016.

[4] Kwakkel, G., Wegen, E. V., Burridge, J., Winstein, C., Dokkum, L. V., Murphy, M. A.,Krakauer, J., Standardized measurement of quality of upper limb movement after stroke: Consensus-based core recommendations from the Second Stroke Recovery and Rehabilitation Roundtable. *International Journal of Stroke*, vol. 14, no. 8, pp. 783-791, 2019.