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MEASURING MOVEMENT FLUENCY DURING THE SIT TO STAND AND SIT TO WALK MOVEMENTS.

¹Andy Kerr, ¹Philip Rowe, ²Danny Rafferty, ²Philippa Dall and ³Valerie Pomeroy

¹University of Strathclyde; email: a.kerr@strath.ac.uk, ²Glasgow Caledonian University, ³University of East Anglia.

SUMMARY

Fluent movement (*smooth, co-ordinated, unhesitating*) reflects an intact and mature motor system and is therefore an important factor in determining its integrity. However it is rarely measured objectively. We provide a quantifiable definition of movement fluency based on three parameters; 1) smoothness (number of inflections in the centre of mass (CoM) jerk signal), 2) co-ordination (temporal overlap of joint movement) and 3) hesitation during movement (reduced velocity before changing movement direction). These measures were tested on groups with and without known impairment (including young and old healthy, stroke survivors and individuals at risk of falling) performing the sit to walk (STW) or sit to stand (STS) movements. Movement fluency varied statistically significantly according to group as well as demonstrating change over the course of a rehabilitation programme. These findings support the use and further development of our definition of movement fluency as well as providing reference data for future researchers and clinicians.

INTRODUCTION

Fluent movement (smooth, co-ordinated and unhesitating), is the visible expression of an intact, mature and efficient motor system. Restoring movement fluency is a central tenet of the dominant approach to the rehabilitation of individuals with neurological conditions such as stroke [1] due to its association with efficiency and function [2,3]. Consequently movement fluency is a key element in assessing motor impairment as well as evaluating the efficacy of therapy. Despite its importance fluency is only measured subjectively by therapists. The development of robots to support exercise therapy for the upper limb has led to definitions of movement such as co-ordination and smoothness which can be adapted to the measurement of fluency during whole body movements. The sit to stand (STS) and sit to walk (STW) movements provide an ideal environment for testing movement fluency variables. The movements are relatively simple, (generally limited to one plane), involve the whole body moving through clear points of postural transition and are amenable to experimental control. In addition they are both functional, everyday movements.

Our primary aim, therefore, was to provide a clinically useful and measurable definition of movement fluency and test its discriminant validity and sensitivity to change across populations with and without known impairments. Movement fluency was defined from three proxy measurements adapted from the literature:

Hesitation during movement: For the STW movement this was calculated as a percentage drop in forward velocity of the centre of mass [CoM] [4], for STS it was the period of overlap between the end of forward CoM velocity and commencement of vertical velocity; the smaller the overlap the more hesitant the movement, zero overlap being a complete stop.

Co-ordination: The temporal overlap between knee and hip movement in the sagittal plane (expressed as a percentage of the whole movement time) [5]. This was calculated for two periods: 1) between the end of hip flexion and start of knee extension (STS and STW) and 2) between the end of hip extension and start of knee flexion (STW only), see fig1.

Smoothness: Number of inflections in the CoM jerk signal [6], each inflection identified using a logic statement that determined a negative or positive change across three consecutive time points, see figure 2.

Figure 1: Measurement of co-ordination during STW

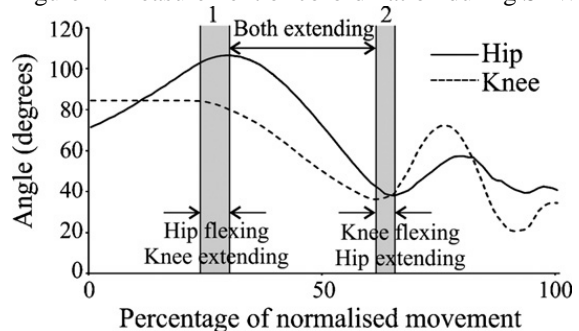
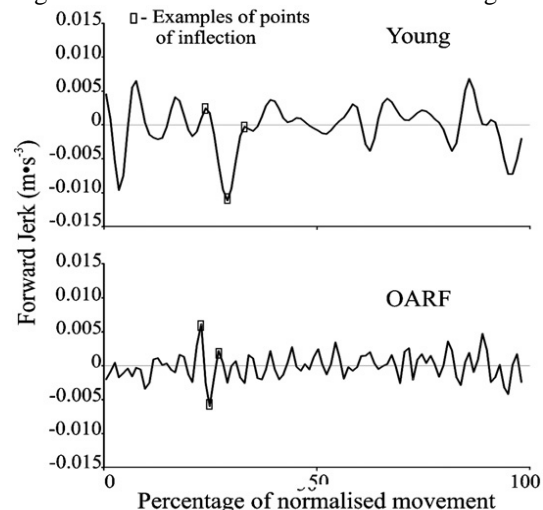


Figure 2: Measurement of smoothness during STW



*OARF=Old at risk of falling

METHODS

Kinematic data were extracted from the database of two separate trials; a biomechanical analysis of the STW movement in older adults [7] and a randomised control trial of physiotherapy in stroke rehabilitation [8]. Both studies had ethical approval. This dataset gave us four distinct groups; 1) **stroke survivors**, pre and post rehabilitation, n=10, age 64.11+/- 11/14, time since stroke 31.8 days +/- 21.2, this group performed the STS movement, 2) **young adults** (n = 20, age 33.1years+/- 8.0) **older adults** (n = 18, age 70.3 years +/- 5.4) **older adults at risk of falling (OARF)** (n = 18, age 79.6 +/- 7.5).

Data Capture

Movement data were captured using three dimensional, motion analysis systems (Vicon, Oxford Metrics, UK and Qualisys Medical AB, Gothenburg, Sweden). Reflective markers were located over anatomical points and clusters of markers were placed on the lower legs, thighs and sacrum. Data were collected at a rate of 50Hz.

Data Analysis

Marker trajectories were filtered using a low-pass 4th order Butterworth filter with a cut-off frequency of 6 Hz, and interpolated with a maximum gap fill of 10 frames using a non-uniform rational B-spline. The resulting data were used to construct a model of the body to allow calculation of joint angles, joint loading and total body CoM movement. The onset time (first continuous forward movement of the CoM) and end time (peak height of CoM for the STS movement and foot contact of first swing phase for the STW movement) were identified for each movement to allow normalisation of the data to 100% of the movement time. Three fluency variables: hesitation, co-ordination and smoothness, were then calculated from the resulting data and tested for statistical variation across the groups.

RESULTS AND DISCUSSION

All three fluency measurements varied statistically significantly across the three groups performing the STW movement. Hesitation was greatest (F = 15.11, p < 0.001) in the OARF, 47.5% (18.0), compared to older, 30.3% (15.9), and younger 20.8% (11.4) adults. Co-ordination (F = 44.88, p < 0.001) was lowest in the OARF with only 6.93% (10.99) of joint overlapping compared to both the young (31.21%, 5.48) and old (26.24%, 5.84). Smoothness (F = 35.96, p < 0.001) was best in the younger adults with 18.3 (5.2) inflections, compared to the old, 42.5 (11.5) and OARF, 44.25 (7.29). For stroke survivors, fluency showed statistically significant changes following rehabilitation. Smoothness (F=3.22, p=0.085) changed from 143.4 (66.0) inflections to 88.6 (68.6). Co-ordination improved (F=9.36, p=0.007) with increasing overlap between hip and knee

movement; 4.48% (3.98) before compared to 13.82% (7.87) after. Hesitation improved (F=6.01, p=0.031) from 19.32% (10.51) to 40.88 % (20.76) of overlap between cessation of horizontal velocity and commencement of vertical velocity.

This study found significant differences in movement fluency across sections of the population with and without impaired mobility and demonstrated changes in fluency following rehabilitation. The discriminant validity and sensitivity to change of these novel measures of human movement support their use in objectively measuring fluency, which is a central component of movement rehabilitation. This will allow greater scrutiny of the effectiveness of rehabilitation interventions as well as shaping future interventions. The methods presented in this paper are not currently translatable to clinical practice due to the cost of the instrumentation and data processing involved, however the definitions and reference data can influence the development and application of body mounted sensors such as accelerometers and gyroscopes which may provide a method of clinically applying these techniques, as would the development of inexpensive, 3D, clinical movement analysis systems.

REFERENCES

- Davidson, W. Physiotherapists working with stroke patients: a national 348 survey. *Physiotherapy* 2000;**86** (2):11.
- Zamparo, et al. The energy cost of level walking in patients with hemiplegia. *Scandinavian Journal of Medicine & Science in Sports* 1995;**5** (6):348–52.
- Thelen (1995) Motor development: a new synthesis. *American Psychologist* 1995;**50** (2):16.
- Dion L, et al. Assessing mobility and locomotor coordination after stroke with the rise-to-walk task. *Neurorehabilitation and Neural Repair* 2003;**17**:83–92.
- Krebs HI et al. Robot-aided neurorehabilitation: from evidence-based to science-based rehabilitation. *Topics in Stroke Rehabilitation* 2002;**8** (4):16.
- Rohrer B, et al Movement smoothness changes during stroke recovery. *Journal of Neuroscience* 2002; **22**:8297–304.
- Kerr, A. et al. Defining phases for the sit-to-walk movement, *Clinical Biomechanics*, 2007 **19**, 385-390.
- Cooke, E.V. et al. Efficacy of Functional Strength Training on Restoration of Lower-Limb Motor Function Early After Stroke: Phase I Randomized Controlled Trial *Neurorehabilitation and Neural Repair* 2010 **24**: 88-96.

Population	Movement	Smoothness	Co-ordination	Hesitation*
Young adults (n=20)	STW	18.25(2.21)	13.16% (6.63)	20.82% (11.43)
Old adults (n=18)	STW	42.50(11.45)	11.33%(13.02)	30.29% (15.86)
Fallers (n=18)	STW	44.25(7.29)	1.47% (9.89)	47.51% (18.00)
Stroke, pre rehabilitation (n=10)	STS	143.4(66.0)	4.48% (3.98)	19.32% (10.51)
Stroke, post rehabilitation (n=10)	STS	88.6(68.6)	13.82% (7.87)	40.88% (20.76)

* for STW a larger value indicates more hesitation, for STS a larger value indicate less hesitation.