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Simulated activities of daily living do not replicate functional upper limb movement or reduce movement variability

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ABSTRACT

Kinematic assessments of the upper limb during activities of daily living (ADLs) are used as an objective measure of upper limb function. The implementation of ADLs varies between studies; whilst some make use of props and define a functional target, others use simplified tasks to simulate the movements in ADLs. Simulated tasks have been used as an attempt to reduce the large movement variability associated with the upper limb. However, it is not known whether simulated tasks replicate the movements required to complete ADLs or reduce movement variability. The aim of this study is to evaluate the use of simulated tasks in upper limb assessments in comparison to functional movements. Therefore answering the following questions: Do simulated tasks replicate the movements required of the upper limb to perform functional activities? Do simulated tasks reduce intra- and inter-subject movement variability? Fourteen participants were asked to perform five functional tasks (eat, wash, retrieve from shelf, comb and perineal care) using two approaches: a functional and a simulated approach. Joint rotations were measured using an optoelectronic system. Differences in movement and movement variability between functional and simulated tasks were evaluated for the thorax, shoulder, elbow/forearm and wrist rotations. Simulated tasks did not accurately replicate the movements required for ADLs and there were minimal differences in movement variability between the two approaches. The study recommends the use of functional tasks with props for future assessments of the upper limb.

1. Introduction

Current assessment of upper limb function of patients with disability or injury is primarily achieved using visual assessment and through quality of life questionnaires that assess pain, functional abilities in activities of daily living (ADLs), emotional well-being and physical strength (Habermeyer et al., 2006). Such methods are subjective and they often suffer from limitations related to reliability (Metcalf et al., 2007, Rocourt et al., 2008, Ellis et al., 1997, Fowler and Nicol, 2001).

Three-dimensional kinematics are not routinely used in assessment of the upper limb, unlike in the lower limb where these tools have been used for decades to provide objective measures of function. This is due to a number of technical difficulties in the measurement and analysis of upper limb movement in comparison to the lower limb. The difficulties include the presence of a thick layer of soft-tissue covering the shoulder region (Shaheen et al., 2011b), the large range of motion achieved by the upper limb and difficulties in choosing appropriate computation methods (Kontaxis et al., 2009) as well as difficulties arising from the wide spectrum of use of the upper limb in ADLs (van Andel et al., 2008, Mackey et al., 2005). Upper limb movements are also associated with large intra-subject (Mackey et al., 2005, Sheikhzadeh et al., 2008, Murray and Johnson, 2004) and inter-subject (van Andel et al., 2008, Sheikhzadeh et al., 2008, Aizawa et al., 2010) movement variability, this hinders interpretation of the measured parameters (Murray and Johnson, 2004, van Andel et al., 2008, Petuskey et al., 2007) and identification of pathological movements (Mackey et al., 2005).

A number of studies have contributed to the development of objective kinematic assessments of the upper limb and have employed a number of tasks to represent ADLs to assess function (Aizawa et al., 2010, Hall et al., 2011, Mackey et al., 2005, Petuskey et al., 2007, van Andel et al., 2008, Sheikhzadeh et al., 2008). Two approaches have been used in these studies to evaluate ADLs; some have made use of props (e.g. a comb, spoon, cup etc.),

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thus allowing participants to perform the actual functional task during measurement (Aizawa et al., 2010, Doorenbosch et al., 2003, Magermans et al., 2005, Veeger et al., 2006), whilst others have made use of movements designed to simulate ADLs (Petuskey et al., 2007, Mackey et al., 2006, Sheikhzadeh et al., 2008). Other studies have used a combination of the two approaches (van Andel et al., 2008) or have not specified how the tasks were carried out (Hall et al., 2011, Murray and Johnson, 2004).

Nevertheless, the majority of the studies making use of simulated tasks over actual functional performance of ADLs have not always clarified the reasons for using this approach, however, it is likely that simulated tasks were used as an attempt to simplify ADLs in order to obtain more repeatable movements, therefore, reducing the high intra-subject and inter-subject variability. A justification for the choice of a simulated approach to reduce the effect of variability has also been explicitly suggested in the study by Sheikhzadeh et al. (2008). However, there is no evidence to show that these tasks are representative of the movement of the upper limb joints when performing real ADLs. In addition, it is not known whether such simulated tasks are indeed able to reduce the reported movement variability.

The aim of this study was to evaluate the use of simulated tasks in ADL studies in comparison with performing functional tasks. We had two research questions: Do simulated tasks produce the same movement (maximum and minimum angles, ranges of motion and temporal characteristics of movement –hereinafter referred to as movement pattern-) as their corresponding functional tasks? Do simulated tasks improve repeatability by reducing intra-subject and inter-subject movement variability compared to functional tasks? We hypothesised that simulated tasks would produce different measures of movement to functional tasks but would reduce movement variability.

2. Materials and methods

2.1. Participants

Fourteen volunteers (8 males) with a mean age of 21.7 ± 1.3 years and no existing or previous upper limb pathology or injury were recruited for the study. Participants provided written consent to take part in the study. The study received a favourable ethical opinion from the University of Surrey Research Ethics Committee.

2.2. Laboratory and subject set-up

An 11-camera Motion Capture System (Qualisys, Gothenburg, Sweden) running at 200 Hz was used and retroreflective markers were attached on the segments of interest using hypoallergenic double-sided tape. The movement of the pelvis, thorax, scapula, humerus, forearm and hand on the dominant side were tracked using these markers. A subject calibration trial was used to define anatomical positions, where markers were attached to the pelvis (Right and Left Anterior Superior Iliac Spine and Posterior Superior Iliac Spine), the thorax (Incisura Jugularis, Process Xiphoideus, Spinal Process of the 7th Cervical and 8th Thoracic Vertebrae), the humerus (Lateral and Medial Epicondyles), the forearm (Radial and Ulnar Styloid Processes) and the hand (3rd Metacarpal). A scapula locator was also used to define the positions of anatomical landmarks on the scapula (Acromial Angle, Inferior Angle and Root of the Scapular Spine) with the arm at 60° elevation in the scapular plane (Shaheen et al., 2011a). In addition to the anatomical markers, 3-marker clusters were attached to the acromion of the scapula (Shaheen et al., 2011), humerus, forearm and hand, these were used to track the movement of the segments in dynamic trials (Kontaxis et al., 2009). In dynamic trials, the anatomical markers on the humerus, forearm and hand were removed.

2.3. Measurement procedure

Participants performed tasks representing ADLs using two approaches; functional tasks (FTs), using clear functional targets with the aid of props where appropriate, and corresponding simulated tasks (STs). The tasks were chosen because they were often used in kinematic assessments of the upper limb and they represented common ADLs: eating, washing, hair combing, retrieving an item from a shelf and perineal care. The order of the ten tasks was randomised for each participant and each task was repeated three times. Participants were not made aware that the STs were intended to represent any particular ADL. Marks on the table/shelf and floor were used to standardise the positions of the props, furniture and participant. Participants were given verbal instructions regarding the start and end position of their hand. The instructions given to the participants for each task are shown in Table 1.

A task representing perineal care was included because of its importance for independent living. In previous studies this task was simulated by touching the back pocket (Doorenbosch et al., 2003, Petuskey et al., 2007, van Andel et al., 2008); such a movement is likely to be different to the movement performed in perineal care. For the FTs, subjects were seated in a custom-made stool and they were instructed to touch a marker attached to the base of the stool. This set-up was believed to provide a more realistic demonstration of the movement involved in perineal care.

2.4. Data analysis

The humeral centre-of-rotation was defined relative to a cluster on the scapula using a functional trial and a least-squares solution (Gamage and Lasenby, 2002). Coordinate frames for the pelvis, thorax, humerus, forearm and hand were defined and Euler rotation sequences were used to compute joint angular rotations based on the recommendations of the ISB (Wu et al., 2005, Wu et al., 2002). The movement of a marker on the hand was used to determine the start and end of movement; this was used to define a movement cycle. Joint rotations were then normalised to 100% of the cycle time, this was to remove the effect of relative timing in completing the movement and allow comparisons between trials and subjects. Following normalisation, mean joint angles from

Table 1
Showing the five activities of daily living (ADL), the instructions given to the subjects for performing a functional task and the corresponding simulated task. Note that in all tasks the starting and finishing positions of the hand were pre-determined.

ADL	Functional task (FT)	Simulated task (ST)
Wash	Use the sponge to wash your contralateral armpit	Touch your contralateral armpit (van Andel et al., 2008, Murray and Johnson, 2004)
Eat	Use the spoon and bowl to feed yourself	Touch your mouth (Mackey et al., 2006)
Comb	Use the comb to comb the centre section of your hair from the front to the back of your head	Pass your hand over your head and touch the back of your neck (Sheikhzadeh et al., 2008, van Andel et al., 2008, Murray and Johnson, 2004, Veeger et al., 2006)
Retrieve from shelf	Retrieve the bottle on the shelf and place it on the table on the cross	Point at the cross on the bottle in front of you (Petuskey et al., 2007) and then point at the cross on the table
Perineal care	Touch the marker on the underside of your seat, going around the back of your body	Touch your back pocket (Doorenbosch et al., 2003, Petuskey et al., 2007, van Andel et al., 2008)

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