A STUDY OF THE USE OF COMPENSATION MOTIONS WHEN USING PROSTHETIC WRISTS

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INTRODUCTION

It is well known that the functional capability of a prosthetic hand is less than that of the natural hand and thus it cannot perform the majority of the tasks a natural hand does, as well or as easily. Of the many consequences from this circumstance is that the prosthetic hand is generally used in a support role when there is a contralateral natural hand available. This is because the prosthesis is unable to grasp objects as flexibly as the natural hand. It is known, from splinting studies of the wrists of unimpaired volunteers, that if the person is not able to present the hand in the correct orientation, even the most flexible hand cannot perform prehensile tasks easily, [1,2]. In the prosthetic circumstance, without a wrist to orientate the hand relative to the object, conventional terminal devices do not grasp as effectively. The user must move their arm in a different way, that allows the prosthesis to be presented to the target in an orientation that will facilitate a secure grasp. A result from this is that there is a very real risk that these compensatory motions use greater ranges of motion, larger forces, or occur more often than necessary with a natural hand. Kidd et al [3], observed that these are three of the conditions likely to induce the changes in the musculoskeletal system that are referred to as injuries of overuse. There are few long term studies of the effect of overuse in prosthesis wearers. It is a well known observation amongst the clinicians that users who do not use their prostheses tend to suffer from the sort of degenerative changes associated with overuse. Less still is known about the effect of the compensatory actions of the contralateral limb.

Ross et al [4,5] have begun to address this absence in the paediatric population, by studying the motions of the users of two forms of wrist, using activities of daily living and a three dimensional motion tracking system (Vicon). The work described here aims to perform a similar study in the adult population. It is clear that if the tasks performed are to be meaningful they have to be selected to match the skills and knowledge of the potential subjects. Thus paediatric tasks must be at the appropriate cognitive level for the subjects, and for any group the tasks must be culturally appropriate. While Ross's tasks aim to engage children below the age of 12, such tasks cannot be expected to be suitable for an adult population. Hence the purpose of this study was to develop a series of tests that can be used by an adult population.

DESIGN

Within the World Health Organization's International Classification on Functioning, Disability and Health (WHO ICF), [6], this assessment is within the *Activity* domain, straddling as it does the areas of *Research* and *Clinical Application*. The two areas have subtly different requirements. If the actions of the assessment are very closely constrained then any deviation from the general population will be easily seen and quantified, but the activity runs the risk of being seen as not being clinically relevant. A more relevant action may be too poorly specified to be reproducible and thus not easily compared test to test, or subject to subject. The method proposed here, aimed to be a tool that would be extended towards clinical assessment. The choice was made that the tasks should be selected to encourage natural bilateral motions. It was anticipated that the prosthesis would be used in a support role, but the tasks would make it necessary to use the prosthesis to complete the task.

In order to make the test manageable, six tasks were chosen from a list of sixteen already employed by Stavdahl in his design of a novel wrist orientation [7]. The selection was made to choose easily achieved tasks that did not create redundant data. This was based on experience of the designers and the use of the tasks in the earlier study.

The tasks were:

1. Hanging clothes on a clothesline with clothes pegs
2. Slicing bread
3. Eating with a knife and a fork
4. Sweeping the floor with a broom
5. Stirring in a pot
6. Cutting with scissors

The subjects were tracked using an eight camera Vicon system. Each participant was marked with 25 markers of different sizes on the head shoulders and arms. They were then recorded performing the tasks and the data processed to generate information concerning the ranges of motion and other kinematic information.

Subjects

Twenty unimpaired subjects were recruited to create a baseline understanding of the tasks. They performed the tasks both normally and impaired, using splints to simulate the use of a prosthetic hand and olecranon suspension socket. Results of the splint study were presented in [8]. Additionally, four prosthesis users were recruited and they performed the tasks using their prostheses. Each subject was instructed to perform the tasks, but no guidance was given as to how they should perform the task so that the resulting actions were spontaneous.

RESULTS

As anticipated, the different tasks resulted in different uses of the prostheses during each activity, allowing the use of the devices to be studied. The tasks fell into three groups: Those where the hands were used independent of each other so that their motions were only constrained by the task (eating and slicing bread); those where the hands needed to co-ordinate to manipulate the tools used (Hanging, Cutting, Stirring); and the last where both hands were on the broom and so they moved in complete synchrony with each other.

The kinematic results showed that there were differences in the motions and angles used by the subjects. One of the most striking actions was performed by a prosthesis user. It was not uncommon to observe that when required to cut a circle in a piece of paper, many subjects used the scissors to hold the paper, when readjusting the position of the hand to grasp and reorient the paper. However one subject then changed direction of cutting, and instead of continuing in the same anticlockwise direction from the top of the circle, she started cutting in the *opposite* direction from the *bottom* of the circle, reducing the need to change the orientation of the paper and so the number of adjustments required.

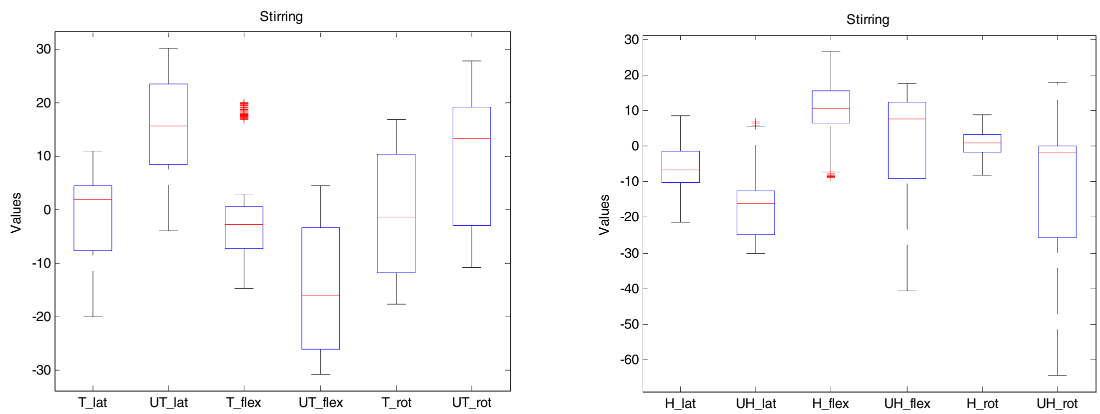

Figure 1 Ranges of motion recorded for both groups
T = Trunk to the left, H = Humerus to the right, , U = Users to the left

Each task has a different emphasis in the use of the prosthesis, the stirring task is chosen here as being a task that requires the two limbs to be loosely connected through the bowl, but it also allows some variation in grasping and use of the tools and prosthesis. Figure 1 shows the recorded ranges of motion for the trunk, and the humerus for the unimpaired side. It can be observed that the compensations are throughout the upper body. The trunk is laterally tilted away from the task in order to allow the restricted movement of the prosthetic side to be accommodated. Similarly the user has to lean forward. The position of the humerus is closer to the unimpaired subjects, but there is a far wider range of motion to compensate for the lack of any stirring performed by the wrist.

Discussion

The level of constraint on the motion of the prosthesis needed to perform a task is an important one when considering the tasks. The constraints mean that greater demands are placed on the arms to position the device in the correct position.

The flaw in not constraining the actions more is that the ranges of motions can thus be as wide as possible. Though the subject who cut both directions round the circle appeared to have found a novel solution to save herself time and effort, a review of the other subjects showed that one of the unimpaired subjects *also* cut this way. Thus it cannot be seen as a diagnostic indication of the difficulty of prosthesis use.

The need for increased range of motion for all the remaining joints of the arms and torso of the users was easily observed. This shows that it is not merely the arm that has the impairment, but the rest of the body that has to compensate for the loss of functional range. Hence when looking for the effect of limb loss or prosthetic design it is important to observe the entire body in detail.

The future direction of this research is to refine the tasks in order to select tasks that naturally constrain the motion and do not allow for too much individual variation, without needing to dictate to the subjects.

REFERENCES

1. Mell A et al "The Effect of Wearing a Wrist Splint on Shoulder Kinematics During Object Manipulation" Ach Phys Rehab, Vol 86, August 2005, pp 1661-1663.
2. Gillen G., et al. "The Effect of Wrist Position on Upper Extremity Function While Wearing a Wrist Immobilising Splint." JPO, Vol 20, No 1, pp 19-23, 2008.
3. Kidd , P.S., MoCoy, C., Steenbergen, L., "Repetitive Strain Injuries in Youths." *Journal of the American Academy of Nurse Practitioners*, Vol.12, No. 10, 2000;pp. 413-426.
4. Ross M "Development of a Quantitative Test For Prosthetic Function Using Motion Analysis and Activities of Daily Living." Master's thesis, UNBrunswick, 2005.
5. MacPhee, Benjamin, "*Examining the prosthetic function and body behavior of prosthesis users performing activities of daily living*.", Department of Mechanical Engineering, University of New Brunswick, Fredericton, New Brunswick, 2007.
6. World Health Organization "Towards a common language for functionary, disability and health: ICF beginner's guide" (WHO/EIP/GPE/CAS/01.3) WHO, Geneva, 2002.
7. Stavdahl, Ø., "Optimal wrist prosthesis kinematics: three dimensional rotation statistics and parameter estimation", Ph.D. thesis, Norwegian University of Science and Technology, Trondheim, Norway, 2002. ISBN 82-471-5526-5.
8. Stavdahl, Ø., et al. "A Prosthetic Wrist with an Oblique Plane of Motion to Optimise Device eight Size and Functionality", 12th ISPO World Congress of the International Society of Prosthetics and Orthotics, August 2007, Vancouver, Canada.