KINEMATIC CHANGES WITH POWERED WRIST FLEXION FOR TRANSRADIAL PROSTHETIC USERS COMPLETING THE GAZE AND MOVEMENT ASSESSMENT (GAMA) PASTA BOX TASK

Laura A. Miller, PhD, CP,[1,2] Quinn A. Boser,[3] Vikram Darbhe,[1,2] Jacqueline S. Hebert, MD,[3] Kevin Brenner,[1] Kristi L. Turner, DHS, OTR/L[1]

[1] Center for Bionic Medicine, Shirley Ryan AbilityLab, Chicago, IL, USA; [2] Northwestern University, Chicago, IL, USA; [3] University of Alberta, Edmonton, Canada

ABSTRACT

Many assessments used to evaluate prosthetic function primarily emphasize task completion time, overlooking the assessment of movement quality or the specific degree of freedom (DOF) activated during the task. For example, proper functioning of the wrist is crucial for accurate hand positioning, but the addition of this movement would likely add time to task completion. Unfortunately, only a limited number of available prosthetic wrists offer powered flexion and extension. As a result, users often need to rely on compensatory body movements, which can lead to injuries and even lead to abandonment of the device. In our study, we used the Gaze and Movement Assessment (GaMA) metric to compare task timing, endpoint trajectories, and 3D angular joint kinematics between a 1-DOF wrist and a 2-DOF wrist combined with a 1-DOF hand. Our hypothesis was that the 2-DOF wrist, though requiring more time, would yield kinematics closer to normative data and result in fewer compensatory movements compared to the 1-DOF wrist. Preliminary results on 4 individuals completing the Pasta Box task and utilizing a powered wrist flexion extension unit showed some changes in torso movements but large variability among the participants. Contrary to our hypothesis there was not a large difference in timing between the two conditions.

INTRODUCTION

Many functional assessments used to evaluate prosthetic function focus on task completion time without considering movement quality or the specific degree of freedom (DOF) activated during the task. To address this limitation, the Gaze and Movement Assessment (GaMA) metric was developed and validated at the University of Alberta under DARPA's Hand Proprioception and Touch Interfaces (HAPTIX) program. GaMA uses motion capture and eye tracking to quantify motion, including 3D angular kinematics and hand movements, as well as gaze behavior during simulated real-world tasks. The GaMA tasks, such as the Cup Transfer Task and the Pasta Box Task, simulate day-to-day functional requirements while challenging typical prosthetic limitations, such as reaching and transporting objects at varying heights and across the body. Each task can be subdivided into specific phases of reaching, grasping, transporting, and releasing objects. A performance aspect encourages the participant to work efficiently, and tasks are short to allow multiple repetitions within a reasonable testing time frame to assess performance consistency.[1, 2]

Previous work has highlighted the importance of wrist dexterity with individuals with intact limbs performing functional tasks while wearing braces to block certain wrist and hand movements.[3] In addition, both the type of terminal device and the presence of wrist motion have been found to impact compensatory movements in prosthetic users. For instance, a study comparing compensatory movements using two myoelectric hooks revealed a significant negative correlation between wrist flexion and shoulder abduction: greater wrist flexion was associated with less shoulder abduction, while ulnar or radial inclination of the wrist did not seem to influence shoulder abduction.

To address the need for wrist function, we designed a 2 DOF wrist that can be combined with a single DOF hand. We hypothesize that the time to complete some tasks would be slower when a wrist flex/extension (WFE) DOF is utilized but the trunk and shoulder compensatory movements, as measured by the GaMA metric, would be decreased.

METHODS

Five individuals have been enrolled and have completed testing with the 2 DOF wrist and Ottobock transcarpal hand controlled with 8 channels of EMG connected to a pattern recognition system.[4] For the Flexion Off condition, the wrist could be locked in a neutral position.

For each condition (Flexion On & Off), the users were trained on the use of the device, functional outcomes, and GaMA tasks by an Occupational Therapist. Functional outcomes included the Box and Blocks test, Southampton Hand

Assessment Procedure (SHAP), Jebsen Taylor Test of Hand Function, the Activities Measure for Upper Limb Amputees (AM-ULA) and the Clothespin Relocation Task. When possible, participants completed a home trial of at least 2 weeks for each condition, with the functional outcomes administered before and after the home trial, and GaMA tasks only administered after. Due to delays from Covid-19, some home trials were forfeit (Table 1). In this case, for each condition, the participant completed training, one set of functional outcomes, and the GaMA tasks.

Figure 1: S1 with device during calibration (Left). S4 completing the Pasta Box task (Right)

The GaMA tasks consist of object movements that are each divided into 4 phases: Reach, Grasp, Transport and Release. The data compared between Flexion On and Flexion Off included the timing for the reach, grasp, transport and release phases of each movement, the endpoint trajectory, and the joint kinematics. During the Flexion On condition, participants began trials with the wrist flexor in a neutral position. For all trials the hand was open and positioned with slight supination so that all motion capture markers were visible. For the current analysis, user data from 4 of the individuals were compared between conditions and to normative data for the Pasta Box task. For the Pasta Box task, participants begin with the hand on the front table in a "home" position. They then turn to the prosthetic side to pick up the pasta box and transfer it to the lower shelf, touch "home" then move the box from the lower shelf to the upper shelf, touch "home", transfer the box back to the starting position and end the trial when the hand returns "home". This allows for a cycle of movements that can be analysed by averaging multiple trials.

Conditions (Flexion Off and Flexion On) were not randomized. All participants completed the Flexion Off condition prior to continuing to the Flexion On condition, since this corresponds to how users would learn and build complexity in a clinical setting.

The remaining data continue to be processed. No statistical analysis has yet been performed; all conclusions reflect visual observation of trends in the metrics (averages across session trials). This study was approved by the Northwestern University IRB and the University of Alberta REB and all participants provided written consent.

RESULTS

Patient demographics are presented in Table 1. All 4 participants had experience with myoelectric prostheses, though S2 had abandoned use. The other 3 all utilized their 2-site system on a regular basis, 3-5 days per week.

Participants did engage the wrist flexor/extensor during the Flexion On condition. The most consistent activation was extension of the wrist during the first portion of the trial (Reach 1), in order to assist with positioning the grasp of the pasta box on the side table. There was otherwise large variability in wrist movements throughout the rest of the trial between participants, but on average the wrist stayed in an extended position. One participant (S1) also chose to rotate the wrist 180 degrees at the start of the trial (so the hand open/close faced away from the midline), however they still engaged the wrist into extension at the start of the trial.

Contrary to our hypothesis, the addition of wrist flexion did not appear to have a large impact on the overall timing of the task. One user did take a bit longer (S3: Off=19.3±2.7s, On=25.6±4.5s) but the other users did not show large changes (S1: Off= 29.9±2.9s, On= 30.4±2.8s; S2: Off= 27.6±6.9s, On= 30.7±7.3s; S4: Off= 29.0±2.0s, On= 27.8±2.1s). These times were much longer than normative trials (11.2±2.0s).

It was hypothesized that there would be reduction in the shoulder and trunk movements with the addition of wrist flexion and extension. However, a clear trend is not seen in the 4 participants analysed to date for the Pasta Box task. For example, Subjects 2 and 3 showed much larger trunk flexion/extension during the first phase of movement, picking up the pasta box from the side table, than Subjects 1 or 3.

Table 1: Participant demographics. * indicates condition was completed with a home trial

	Prosthetic side	Primary home device at time of participation	Number of trials per condition	
			Flexion OFF	*Flexion ON*
S1	Right	2-site myo: Taska, passive wrist	11 *	10 *
S2	Left	Abandon use	10 *	10
S3	Left	2-site myo: Bebionic, passive wrist	11 *	12 *
S4	Right	Body powered: TRS Jaws	10	10

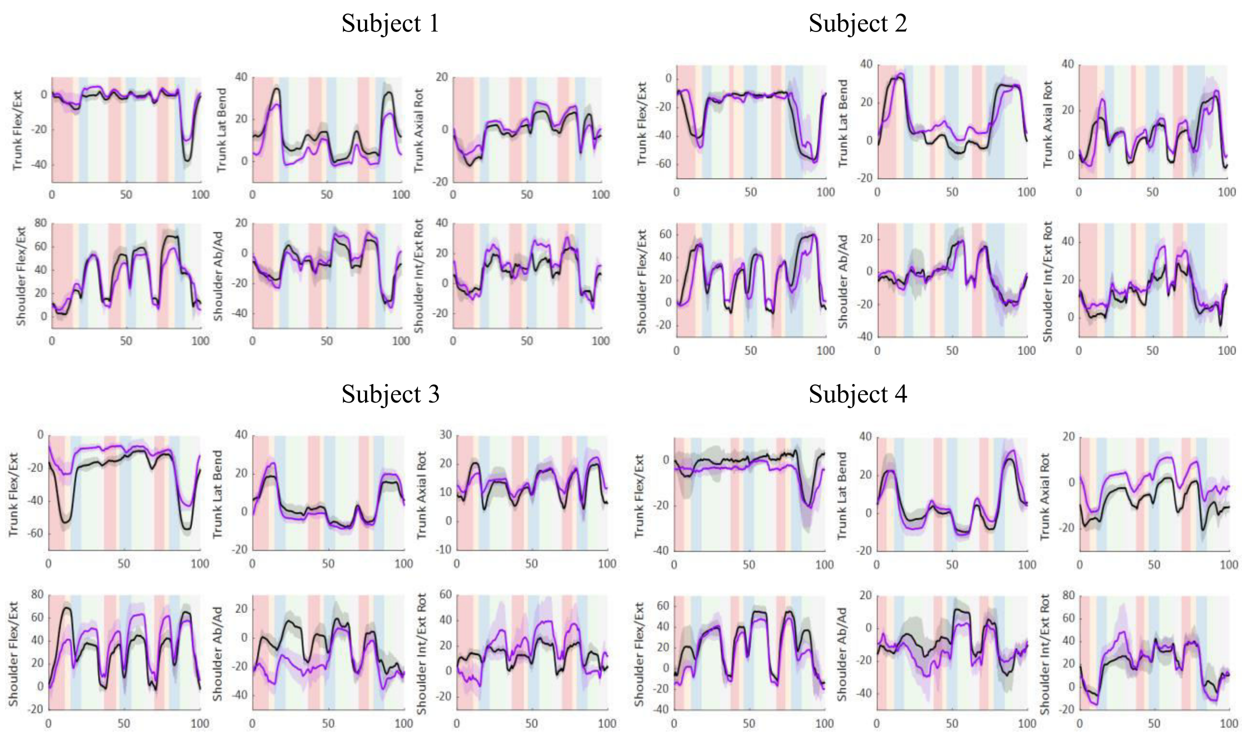

Figure 2: Kinematics for the Pasta Box task. For each subject: Top row- Trunk Flexion/Extension, Lateral Bend, & Axial Rotation. Bottom- Shoulder Flexion/Extension, Ab/Adduction, & Internal/External Rotation. Flexion Off is shown in Black, On is shown in Purple. Standard deviations are shown as a shaded band. Vertical shading indicates the timing of the task (Reach-pink, Grasp-yellow, Transport-blue, Release-green, Return Home-Gray).

The addition of Wrist Flexion/Extension resulted in decreased range of motion in some Trunk and Shoulder degrees of freedom, for two participants (S1 and S3). However, it also then resulted in increased Shoulder Internal/External rotation for S2 and S3 (Table 2). This increased internal rotation mostly occurred when the participants were placing or picking up the box at the second shelf, which may have been a consequence of the extended wrist position.

DISCUSSION

Despite initial expectations, participants did not, overall, take longer to complete the Pasta Box task with the addition of wrist flexion and extension. However, for both conditions, they were slower than the normative data. The participants did consistently utilize the wrist flexion and extension unit during the second condition to extend the wrist at the beginning of the Pasta Box Task trials. After grasping the box on the side table, some participants continue to activate the wrist F/E throughout the task, while mostly holding the extended wrist angle. However, variability is high. There does not appear to be a consistent strategy for use of the wrist flexion and extension degree-of-freedom between or within participants. This variability is also reflected in the kinematics of the shoulder and trunk. Though the addition of wrist flexion and extension did result in a decrease in range of movement at the trunk and shoulder for two participants, increases were also seen in internal and external shoulder rotation. As previously mentioned, this increase occurred during the phase of the trial when the participant would place or pick up the pasta box on the highest shelf across the body. This may be because of additional compensation made from the extended position of the wrist or to stabilize the arm for better control of the hand grasp and release.

Table 2: Total Range of Motion for the Trunk and Shoulder for each condition: Average (Standard Deviation)

	Controls	S1		S2		S3		S4	
		Off	On	Off	On	Off	On	Off	On
Trunk Flex/Ext	10.2 (3.2)	44.3 (3.7)	32.6 (3.1)	51.4 (1.7)	55.6 (3.1)	51.3 (4.2)	42.6 (4.6)	29.4 (8.8)	28.9 (5.1)
Trunk Lateral Bend	17.7 (4.7)	36.6 (2.4)	30.7 (2.1)	41.9 (4.0)	36.8 (2.6)	29.7 (3.9)	36.9 (3.8)	40.2 (3.6)	48.1 (3.3)
Trunk Axial Rot	23.0 (5.4)	23.4 (2.5)	22.9 (1.7)	34.1 (2.0)	38.3 (2.5)	21.0 (1.5)	21.3 (6.5)	26.7 (3.7)	26.2 (2.4)
Shoulder Flex/Ext	86.3 (8.6)	74.1 (6.8)	58.7 (4.2)	76.9 (4.7)	73.7 (3.8)	80.3 (5.3)	76.5 (11.7)	83.1 (7.0)	77.3 (10.1)
Shoulder Abd/Add	27.7 (7.0)	50.7 (6.4)	53.2 (4.9)	47.4 (8.5)	49.6 (13.4)	56.9 (8.5)	51.6 (6.9)	50.8 (11.9)	48.3 (13.0)
Shoulder Int/Ext Rot	41.8 (7.9)	48.4 (6.8)	52.9 (3.4)	39.6 (3.6)	45.9 (4.5)	36.9 (5.4)	74.3 (18.7)	63.4 (11.9)	76.8 (20.1)

There are limitations to this current analysis. Currently only trials from four of the five participants have been processed. Once all trials have been completed a more in-depth evaluation of the results, including statistical analysis, can take place. We have also noted that wrist angles are also somewhat variable for normative data, and it may be that for the Pasta Box task it is more difficult to clearly identify the impact of wrist flexion. The GaMA metric also includes a second task, the Cup Transfer task. In that task, participants move small plastic cups from one of a table to the other and then back. One cup is picked up from the top and the other from the side. This task may show a more consistent use of the wrist flexion and extension movement that would allow a more direct analysis of the influence on shoulder and trunk compensation. As data analysis is completed, we expect that the GaMA metric will assist in evaluating use of additional DOF for prosthetic componentry, and compensatory movements. The kinematic analysis can serve as a supplement to other timed outcome measures, such as the box and blocks and the SHAP to quantify compensatory movements that are not well evaluated and scored in other measures.

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