KINEMATIC COMPARISON OF BODY-POWERED AND MOELECTRIC PROSTHESES IN USERS WITH TRANSRADIAL AMPUTATIONS

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ABSTRACT

Objective: The purpose of this study was to quantify differences in shoulder, elbow, and wrist range of motion between myoelectric and body powered prosthesis users during three simulated ADLs. ROM of the involved limb and the sound limb were also compared. It was hypothesized that amputees utilizing a myoelectric prosthesis would exhibit less ROM for a given task compared to that of body powered users, and that the prosthetic limb would require greater ROM in all joints than the sound limb to accomplish a task.

Methods: Three subjects participated in this project. One subject used a myoelectric prosthesis, one used a body-powered prosthesis, and one subject used both. Volunteers performed three simulated ADL's with their sound and prosthetic limb: object transfer, drinking from a cup, and hair combing. Three dimensional kinematic data were collected using an eight camera passive optical motion capture system (Vicon, Denver, CO). A 23-marker model was used for data collection. During processing, the markers were manually labeled and gaps were filled using a Woltring algorithm. Upper-limb joint kinematics were modeled to quantify shoulder, elbow, and wrist ROM on the amputated and sound limb during the three selected tasks. Each task was repeated three times, and the middle trial of each task was used to minimize learning effect.

Results: Using the prosthesis did not necessarily require greater ROM in all joints than the sound side in all subjects. All subjects exhibited different movement strategies; body-powered subject 1 typically used the least ROM and body-powered subject 2 used the greatest ROM to accomplish tasks despite identical componentry. The subject that used both a myoelectric and body-powered prosthesis tended to use greater ROM with the myoelectric prosthesis to accomplish tasks.

Conclusion: This pilot study with a small sample size provided unexpected results and highlighted the importance of socket comfort, formal prosthetic training, and choice of components as critical factors prosthetists can control that affect ROM in users of transradial prostheses.

INTRODUCTION

In an early study centered around the time of initial myoelectric clinical acceptance in 1983, Stein and Walley compared myoelectric and body-powered prostheses through a series of standardized tasks. Users of myoelectric prostheses scored higher in tests of functional range of motion, and were able to carry out the tasks with less compensatory movements. They also found that body-powered users took 2.5 times longer and myoelectric users took 5 times longer to complete the tasks as compared to their sound side. This was a primary study and used as a basis for later research [1].

Carey et al found that users of transradial myoelectric prostheses had decreased humeral flexion and increased elbow flexion when compared to able-bodied individuals while drinking from a cup [2]. Additionally, Metzer et al discovered users of transradial prostheses had larger shoulder and elbow path distances than in able-bodied subjects while performing ADLs [3].

The prosthesis best suited for the amputee's needs depends on control, function, feedback, cosmesis, and rejection according to a systematic literature review by Carey et all in 2015. This review focused on differences between myoelectric and body-powered prostheses. They concluded that current evidence is insufficient to show functional differences between myoelectric and body-powered prostheses [4].

This study will attempt to address this lack of evidence in functional differences between myoelectric and body-powered prostheses by determining functional differences between motion envelopes of myoelectric and body-powered prostheses. This data will be compared to provide insight into compensation strategies within subjects between their sound and amputated side as well as between users of myoelectric and body-powered prostheses.

METHODS

Participants

Unilateral transradial amputees with residual limb length ranging from extremely short to a wrist disarticulation were included in this study. Subjects were users of a myoelectric or body powered prosthesis for at least six months or more, and were screened to ensure they had the range of motion required to operate their prosthesis. Subjects under the age of eighteen were excluded from this study as well as subjects with a neurological or musculoskeletal pathology that impairs arm motor control. Additionally, subjects that had weakness in their forearm defined as a manual muscle testing score of 3+ or less on their amputated arm were excluded from the study.

Experimental Protocol

Once the subjects arrived at UH-Clearlake's facility they signed a consent form and were tested for strength and range of motion to verify that they qualify for the study. Then, they answered a brief survey inquiring about their time since amputation, cause of amputation, years of prosthetic experience, socket comfort score, and completed the Upper Extremity Function section of the OPUS (Orthotics and Prosthetics Users Survey) outcome measure questionnaire. Reflective markers were placed on the subjects and motion analysis was conducted after the questionnaires were completed.

Participants were asked to execute one goal-oriented task listed on the Southhampton Hand Assessment Procedure (SHAP), and two goal-oriented tasks from the Upper Extremity Function section of the OPUS. All tasks were completed while seated in a chair at a table of standard height at 18.25 inches and 28 inches respectively.

1. Lifting and transferring a weighted object- a standard mason jar was closed with a lid. The subject must lift the jar with the prosthetic side, transfer it one foot as specified with tape on the table over a two inch barrier, and set the jar down on the tape.

2. Drinking from a cup-an empty standard sized Solo cup was used. They grasped the empty cup without crushing it and lifted it up to their mouth as if to drink.

3. Hair combing- a comb was raised from the top of their head to the back of their head above their hair.

All of these tasks required grasping an object that can be done with any terminal device in the same neutral position. Participants were asked to complete task requirements as accurately and quickly as possible. Each subject started and ended each task with their arms resting on the table in a neutral position. They were permitted practice to familiarize themselves with the task prior to data collection. Each task was repeated three times with their amputated side first, then repeated three times with their sound side.

Data collection and analysis

Kinematic data collection of upper extremity joint angles, patterns, and positions were accomplished using an eight camera passive optical Vicon 3D Motion capture system. Approximately 23 reflective markers were adhered to the skin or clothing using double-sided tape in a standard configuration consistently placed on subjects by the same individual. The three dimensional coordinates of marker data were used to reconstruct joint angles, calculating kinematic parameters using an upper-body model plug-in with the NEXUS (Vicon Nexus, Denver, CO) software.

The anatomical locations of the markers used in this analysis include: C7 spinous process, T10 spinous process, right scapula, sternum, bilateral acromion processes, bilateral triceps, bilateral biceps, medial and lateral epicondyles, bilateral forearms, radial and ulnar styloids, and bilateral third MCP joint. The epicodyle, forearm, styloid, and third MCP joint markers on the prosthetic side were placed at the relative position of the anatomical locations on the subject's sound side.

Statistical analysis

A 23-marker model was used for data collection. During processing, the markers were manually labeled and gaps were filled using a Woltring algorithm with a minimum gap length of 5 consecutive points. Upper-limb joint kinematics were modeled to quantify shoulder, elbow, and wrist ROM on the amputated and sound limb during the three selected tasks. Joint kinematics were taken of the middle trial of each task to minimize learning effect. The only cases in which the middle trial was not analyzed included if the task was not completed or an anomaly occurred that prevented processing of the task.

Joint kinematics were exported to Excel and absolute maximum and minimum joint range of motions were found using Excel formulas for each task. The absolute maximum and minimum joint range of motions were subtracted to find the total change in joint angles in degrees. This was done for the sagittal, coronal, and transverse planes of the shoulder, the sagittal and coronal planes of the wrist, and the sagittal and the sagittal plane for the elbow. Angular velocity is still being calculated.

RESULTS

Three subjects with traumatic amputations participated in this study. One subject used a myoelectric prosthesis, one used a body-powered prosthesis, and one used both a myoelectric and body-powered prosthesis. The subject using a myoelectric prosthesis was right hand dominant and her amputated side was her left side. The other two subjects were right hand dominant and became left hand dominant after their right side was amputated. The subject that was only tested using a body-powered prosthesis also has a partial hand amputation on his left side.

Experience using a prosthesis ranged from 1.5 to 19 years. Socket comfort scores averaged a 7.5 rating out of a 10 point scale. Average age, height, and weight were 57.3 years, 5'9, and 180lbs. Average time of prosthetic wear was 12 hours. Residual limb length ranged from 4 inches to 8

inches. A comprehensive chart of subject information can be found in Table 3, but notably both myoelectric prostheses had wrist rotators and both body-powered prostheses had figure of 9 harnessing, friction wrists, and 5XA hook terminal devices. One subject using a myoelectric prosthesis used a hand as the terminal device, while the other used an electronic hook as the terminal device.

Please refer to Figures 1-4 and Tables 1-3 to reference numerical results. Results indicated the prosthetic side did not necessarily require greater ROM than the sound side in all subjects and in all joints. The results indicated an even split between whether the prosthetic side or sound side used more ROM. Both subjects that used body-powered prostheses exhibited different movement strategies; body-powered subject 1 typically used the least ROM and body-powered subject 2 used the greatest ROM to accomplish tasks. The subject that used both a myoelectric and body-powered prosthesis tended to use greater ROM with his myoelectric prosthesis to accomplish tasks.

DISCUSSION

Myoelectric subject 1 (Myo 1) and body-powered subject 2 (BP 2) used greater ROM in all planes in all tasks than the subject that was tested using both his myoelectric and body-powered prosthesis (Myo 2 and BP 1). This could have been due to differences in time since amputation. Myo 1 had their amputation a year and a half prior to testing and BP 2 had their amputation 2 years prior to amputation. Meanwhile, the subject listed as Myo 2 and BP 1 had more experience using both of his prostheses. This increased experience may mean increased proficiency performing ADLs, which may have enabled the subject to use less ROM to accomplish tasks.

The differences in ROM between the two body-powered subjects may be explained by time since amputation as previously discussed. Additionally, two other factors may have affected this difference- the amount of formal training the subject had with the prosthesis and their self-reported Socket Comfort Scores. BP 2 reported extensive Occupational Therapy training with the prosthesis, while BP 1 had minimal Occupational Therapy training with the prosthesis. This lack of formal training may have contributed to why BP 2 had increased ROM in all tasks compared to BP 1.

Furthermore, BP 1 had a self-reported Socket Comfort Score of 8 out of 10 when asked how comfortable he found his prosthetic socket, while BP 2 rated his prosthetic socket at 6 out of 10. Since BP 1 found their socket comfortable and BP 2 stated they found their socket uncomfortable, this may have contributed to the difference in ROM in the two subjects. BP 2 may have used more ROM in each task to accommodate for an ill-fitting socket.

Myo 1 used more ROM than Myo 2, which may have been due to the subject's time since amputation as previously discussed. However, hand dominance and

prosthetic components may have also contributed to the differences in ROM. Myo 1 remained right hand dominant after the amputation, whereas Myo 2 had to switch hand dominance from right to left after the amputation. Perhaps the biggest reason for this difference in ROM was due to componentry. Myo 1 used a hand as the terminal device of the prosthesis, while Myo 2 used an electric hook (ETD) as their terminal device. The anatomical hand cover on Myo 1's terminal device results in decreased line of sight, which may explain the increased ROM used to grasp and manipulate objects.

There seemed to be no correlation between the self-reported level of difficulty from the OPUS survey and the ROM measured from the subject using motion analysis. A future study could also include movement of the furthest point, or finger marker, from the torso, or T10 marker, as this measurement would be of excursion the body captures necessary to operate the prosthesis, rather than the total ROM of each joint.

CONCLUSION

This case series analysis does not support the commonly held clinical opinion that users of body-powered prostheses typically use more ROM than users of myoelectric prostheses to accomplish ADLs. Additionally, the prosthetic side did not use substantially more ROM than that of the sound side to complete the three tasks. The small sample size in this pilot study produced unexpected results that indicate common held clinical opinions may need to be reexamined.

This pilot study highlighted the importance of socket comfort, formal prosthetic training, and choice of components as critical factors prosthetists can control that affect ROM in users of transradial prostheses. Hand dominance and time since amputation should also be considerations when deciding on a type of prosthesis and components for a patient to avoid limiting their ROM. Furthermore, the results from this study emphasize the importance of using motion capture to investigate ROM in upper-limb prosthesis users as well as outcome measures for a more accurate analysis.

FIGURES AND TABLES
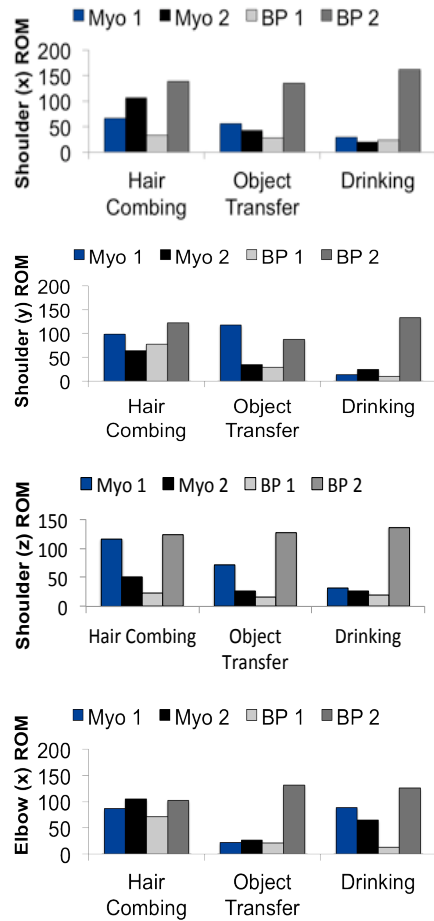
Figures 1-4: Degrees of shoulder flexion/extension (x), ab/adduction (y), int/external rotation (z), and elbow flex/ext (x) ROM during tasks.

Table 1: Comparison of shoulder, elbow, and wrist ROM in degrees between prosthetic (PS) and sound (SS) limb during hair combing.

	Myo 1		Myo 2		BP 1		BP 2	
	PS	SS	PS	SS	PS	SS	PS	SS
Sho (x)	66.3	76.5	106.6	57.9	32.9	57.9	138.6	118.8
Sho (y)	98.3	51.1	63.6	61.2	77.5	61.2	122.7	91.5
Sho (z)	115.9	117.4	51.2	68.0	22.3	68.0	122.9	89.5
Elb (x)	86.4	87.0	105.1	67.3	71.4	67.3	102.0	106.8
Wri (x)	58.0	83.4	32.0	5.3	135.4	5.3	65.6	58.2
Wri (y)	19.4	73.8	23.5	3.0	44.0	3.0	88.6	31.0

Table 2: Comparison of shoulder, elbow, and wrist ROM in degrees between prosthetic (PS) and sound (SS) limb during object transfer.

	Myo 1		Myo 2		BP 1		BP 2	
	PS	SS	PS	SS	PS	SS	PS	SS
Sho (x)	55.8	115.1	42.5	40.9	27.9	40.9	135.2	54.6
Sho (y)	118.1	116.2	34.8	34.4	29.1	34.4	87.6	32.8
Sho (z)	71.1	109.5	27.3	58.2	15.9	58.2	127.2	61.0
Elb (x)	21.9	97.1	26.8	25.9	21.6	25.9	131.2	52.8
Wri (x)	2.9	38.3	2.2	26.4	4.7	26.4	46.6	9.0
Wri (y)	2.3	10.2	1.2	15.2	2.8	15.2	4.8	5.9

Table 3: Comparison of shoulder, elbow, and wrist ROM in degrees between prosthetic (PS) and sound (SS) limb during drinking.

	Myo 1		Myo 2		BP 1		BP 2	
	PS	SS	PS	SS	PS	SS	PS	SS
Sho (x)	29.5	21.4	20.1	22.2	23.3	22.2	161.8	93.6
Sho (y)	13.5	39.8	24.2	15.8	10.3	12.9	133.4	80.0
Sho (z)	31.0	18.0	26.4	17.5	20.0	17.5	136.4	150.3
Elb (x)	88.4	113.9	64.6	81.2	13.1	81.2	126.0	144.1
Wri (x)	11.9	6.3	3.8	21.7	10.2	21.7	77.8	65.1
Wri (y)	9.8	15.2	3.7	10.1	5.3	10.1	72.8	45.1

EQUATIONS

For purposes of this study only the total change in ROM in degrees is compared. Angular velocity for all data is still being calculated.

absolute maximum- absolute minimum   ROM total

(change in ROM) / .01   Angular vel.

REFERENCES

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