COMPARATIVE EFFECTIVENESS AND FUNCTIONAL PERFORMANCE OF MULTIPLE DEGREE OF FREEDOM PROSTHETIC HANDS IN INDIVIDUALS WITH UNILATERAL TRANSRADIAL OR WRIST DISARTICULATION AMPUTATION

F. Clay Smither MD[1], Joseph Webster MD[1], Matthew Borgia MA[2], Sam Phillips[3], Linda Resnik PT, PhD, FAPTA[2]

[1]Hunter Holmes McGuire VA Medical Center, Richmond, VA, USA

[2]Providence VA Medical Center, Providence, RI, USA

[3]James Haley VA Medical Center, Tampa, FL, USA

ABSTRACT

The stated goals of multiple degree of freedom (DOF) prosthetic hands are to improve function and create more natural movements for the prosthetic user. This cross-sectional observational study tested 75 persons with unilateral transradial or wrist disarticulation amputation using standardized measures. Three subtypes of prostheses were compared: body-powered, myoelectric single-DOF terminal device, and myoelectric multi-DOF terminal device. In most categories there was no significant difference in performance with the multi-DOF devices. Body-powered users had better scores in two measures of dexterity compared to myo multi-DOF users. Myo single-DOF users performed better than body-powered users in one test of everyday activities.

INTRODUCTION

Multiple degree of freedom (DOF), or multi-articulating prosthetic hands are arguably the most advanced prosthetic terminal devices. The benefit of these devices includes the more lifelike hand appearance[1] and the ability to assume multiple different hand positions and grasp patterns[2] which, in theory, can enhance performance in a variety of activities. Device manufacturers also report that individual finger motion allows more natural and coordinated movements and greater precision control over delicate tasks.

However, there is limited research examining functional performance of persons using these devices. The purpose of this presentation is to compare dexterity and activity performance of users of multi-DOF myoelectric, single-DOF myoelectric and body-powered devices.

METHODS

A cross-sectional, observational study was conducted. The VA Central Institutional Review Board (IRB), Regional Command-Central IRB and the Human Research Protection Office (HRPO) reviewed and approved this study. All study participants gave voluntary informed consent.

This report is a sub analysis of a larger study of prosthesis users. Exclusion criteria included inability to wear a prosthesis for 3 hours, and any health condition that would limit participation in the study activities. The analysis presented here is limited to participants with unilateral amputation at the transradial or wrist disarticulation level.

Data was collected at one of five sites by either occupational or physical therapists. Demographics, directed history, prosthesis evaluation and physical examinations were obtained and performed. A prosthetist evaluated photographs of the prosthesis to confirm device type. Standardized measures of performance were taken, including Jebsen-Taylor Hand Function (JTHF)[3], Nine Hole Peg (NHP)[4], Box and Block[5], Southampton Hand Assessment Procedure (SHAP)[6], Activities Measure for Upper Limb Amputation (AM-ULA)[7], Brief Activities Measure for Upper Limb Amputation (BAM-ULA)[8], and Timed Measure of Activity Performance (T-MAP)[9].

Prosthesis type was classified as: body-powered, myoelectric single-DOF terminal device, and myoelectric multi-DOF terminal device. Kruskal-Wallis tests were used to compare outcomes by prosthesis type. Dunn's post-hoc tests were used to identify differences between categories of prosthesis type for all outcomes.

RESULTS

Seventy-five persons with unilateral transradial or wrist disarticulation amputation were included in this analysis. Table 1 provides demographics and prosthesis type. The participants were 97% male with mean age of 57. Trauma caused most limb loss. Table 2 describes the measures.

Kruskall-Wallis results are shown in Table 3. There were significant differences by group in JTHF small objects and heavy can items, NHP and BAM-ULA scores. Statistically significant post hoc comparisons are shown in Table 4. Users of body-powered devices had better scores of the JTHF small object tests and NHP as compared to myo multi-DOF users. BAM-ULA scores were better for myo single-DOF users as compared to body powered users.

SUMMARY & CONCLUSIONS

Despite the reported benefits of multiple degree of freedom prosthetic hands, we found no differences in fine motor or everyday activities between those using myoelectric multi-DOF terminal devices and myoelectric single-DOF devices. We did find that users of body powered prostheses had better dexterity scores on 2/10 of tests. In a test of ability to complete everyday tasks, persons using single-DOF myoelectric prostheses performed better than persons using body powered devices.

Prior studies have compared the performance of persons using body-powered and myoelectric prostheses. Hebert et al. studied a single person with transhumeral amputation performing a box and blocks test with a body-powered prosthesis, then 13 months after targeted muscle reinnervation and training with a myoelectric prosthesis. He was able to move 49 blocks with a body-powered prosthesis but only 20 blocks with the myoelectric prosthesis. Motion analysis showed less compensatory trunk movements with the myoelectric device and more natural elbow movement.[10]

Meredith compared the Ottobock Electric Hand, Ottobock Griefer, Hosmer Senergetic Prehensor and body-powered hook in NHP, Box and Blocks and JTHF tests. They evaluated three subjects with transradial amputations, two of whom used a body-powered hook daily and one who used a myoelectric hand. The subjects were trained with Greifer and Synergetic Prehensor prior to testing. In NHP, all three were fastest with Synergetic Prehensor. In the other two tests, the fastest times were distributed between the different devices.[11]

When considering why persons using body-powered prostheses performed better on the NHP and JTHF small items, it may be that multi-DOF terminal devices are complex to use and thus slower to control in fine motor movements, particularly given the need to change grasp patterns and to select the most appropriate grasp for specific tasks.

Our study found that persons using myoelectric single-DOF prostheses had higher scores than body powered users on the BAM-ULA, indicating that they were able to complete more activities as compared to body powered users. Given our findings, we compared scores of individual tasks of the BAM-ULA using Fisher's exact tests to determine if there were specific items that were driving BAM-ULA sub-group differences. We found that scores differed in two items: remove cap from water bottle and drink and lift one-gallon jug. It is likely that body powered users had difficulty regulating grip force in grasping the water bottle, and that they lacked the grip strength and/or could not position their terminal devices to lift the one-gallon jug.

These findings should be considered preliminary due to small sample sizes for groups. Additionally, we did not control for training or years of experience. Subjects were tested using their own prostheses, and some of the tasks tested were not activities that the users routinely performed with their prosthesis (such as brushing hair). Future study involving larger sample sizes are needed to confirm or refute these finding and to evaluate differences by prosthesis make and model.

Table 1: Demographics and Prosthesis Characteristics of Participants

	Body powered (N=45)	**Myo single-DOF (N=12)**	**Myo multi-DOF (N=18)**	**All (N=75)**
	Mn (sd)	**Mn (sd)**	**Mn (sd)**	**Mn (sd)**
Age	62.8 (16.2)	45.8 (16.1)	48.4 (14.3)	56.6 (17.3)
Years since amputation	30.9 (20.5)	14.8 (12.9)	16.5 (15.9)	24.2 (19.7)
	N (%)	**N (%)**	**N (%)**	**N (%)**
Gender				
Male	45 (100.0)	11 (91.7)	17 (94.4)	73 (97.3)
Female	0 (0.0)	1 (8.3)	1 (5.6)	2 (2.7)
Etiology of amputation*^				
Congenital	2 (12.5)	0 (0.0)	1 (16.7)	3 (13.0)
Combat	20 (51.3)	4 (50.0)	3 (21.4)	27 (44.3)
Accident	16 (41.0)	6 (75.0)	8 (57.1)	30 (49.2)
Burn	2 (5.1)	1 (12.5)	1 (7.1)	4 (6.6)
Cancer	2 (5.1)	0 (0.0)	2 (14.3)	4 (6.6)
Diabetes	1 (2.6)	0 (0.0)	0 (0.0)	1 (1.6)
Infection	7 (18.0)	0 (0.0)	1 (7.1)	8 (13.1)

*Etiology of amputation: respondents could indicate multiple etiologies

^ Etiology of amputation was not collected for all participants

Table 2: Description of Performance Measures

	Construct	Item Content	Rating Criteria	Interpretation
Jebsen-Taylor Hand Function (JTHF)	Dexterity	7 separate tests of fine motor activities: writing, page turning, small objects, eating, placing checkers, light cans, heavy cans	Performance speed; items / per second (modified scoring)	Higher scores are better
Nine Hole Peg	Dexterity	Accurately place and remove 9 plastic pegs into a pegboard	Timed Measure; item/s second (modified scoring)	Higher scores are better
Box and Block	Dexterity	Number of wooden blocks transported in 60 seconds	Performance speed; Total number of blocks transported	Higher scores are better
Southampton Hand Assessment Procedure (SHAP)	Dexterity/ Index of Function	26 unilateral timed tasks of hand function: 12 abstract tasks and 14 activities of daily (such as zipping, pouring, buttoning).	Performance speed	Higher scores are better
AM-ULA	Activity performance	18-everyday tasks: brush/comb hair, don t-shirt, doff t-shirt, button shirt, zip jacket, don socks, tie shoes, drink from a cup, use fork, use spoon, pour 12 oz can, write, use scissors, turn doorknob, hammer nail, fold towel, use phone, reach overhead	Each item is rated on: task completion: speed, movement quality, skillfulness of prosthesis use and independence.	Higher scores are better
BAM-ULA	Activity performance	10 everyday tasks: tuck in shirt, lift 20 lbs, open and drink from water bottle, remove wallet from back pocket, replace wallet, lift gallon jug, open and pour jug, brush/comb hair, use a fork, open door with round knob	Ability to complete each task (yes/no). Total score is the number of completed activities	Higher scores are better
T-MAP	Activity performance	5 everyday activities: drink from a cup, wash face, food preparation, eating, dressing	Timed Measure: sum of time to complete each activity	Lower scores are better

Table 3: Functional Outcomes by Device Type

	Body powered (N=45)	Myo single-DOF (N=12)	Myo multi-DOF (N=18)	Kruskal Wallis
	Mn (sd)	**Mn (sd)**	**Mn (sd)**	**p**
Dexterity				
JTHF				
Writing	0.49 (0.30)	0.41 (0.26)	0.52 (0.30)	0.4274
Page turning	0.13 (0.09)	0.14 (0.10)	0.12 (0.07)	0.8182
Small objects	0.11 (0.07)	0.11 (0.11)	0.07 (0.09)	**0.0288**
Eating	0.18 (0.12)	0.17 (0.14)	0.14 (0.09)	0.4160
Checkers	0.08 (0.06)	0.08 (0.09)	0.12 (0.08)	0.0957
Light cans	0.20 (0.13)	0.22 (0.11)	0.28 (0.15)	0.2295
Heavy cans	0.20 (0.17)	0.26 (0.12)	0.25 (0.14)	**0.0481**
Box and Blocks	19.00 (8.73)	14.27 (7.88)	15.28 (6.19)	0.0645
Nine Hole Peg	0.06 (0.05)	0.06 (0.06)	0.01 (0.01)	**0.0008**
SHAP IOF	42.4 (18.4)	39.3 (23.1)	40.2 (15.0)	0.8828
Activity Measures				
AM-ULA	14.9 (5.3)	14.9 (7.7)	16.4 (6.5)	0.5800
BAM-ULA	6.6 (2.1)	9.2 (1.0)	8.0 (1.6)	**0.0023**
T-MAP (mins)	5.0 (1.8)	3.9 (0.6)	3.9 (0.9)	0.0810

Table 4. Statistically Significant Group Differences: Results of Dunn's Test

	Body powered vs. myo single-DOF	**Body powered vs. myo multi-DOF**	**Myo single-DOF vs multi-DOF**
JTHF Small objects	No difference	Body powered is better	No difference
JTHF Heavy cans	No difference	No difference	No difference
Nine Hole Peg	No difference	Body powered is better	No difference
BAM-ULA	Myo single-DOF is better	No difference	No difference

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