FUNCTIONAL OUTCOMES OF A TRANSRADIAL PROSTHESIS WITH AND WITHOUT WRIST FLEXION AND EXTENSION

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ABSTRACT

This study explores the function of a 2-degree-of-freedom (DOF) prosthetic wrist compared to a single-degree-of-freedom wrist for people with below-elbow amputation. The study involves five participants who wore a custom-made 2DOF wrist system and an Ottobock Transcarpal hand, using pattern recognition-based control. Participants did in-lab tests in two conditions: wrist rotation only and wrist rotation with flexion/extension. Functional outcomes, including the Southampton Hand Assessment Procedure, Box and Blocks Test, Jebsen Taylor Test, Activity Measures for Upper Limb Amputees, Clothespin Relocation Task, and Assessment for Capacity of Myoelectric Control, were measured. Preliminary results show little difference between the two conditions, possibly due to the additional addition length, mass, or control complexity.

INTRODUCTION

The wrist plays a crucial role in human dexterity, positioning the hand for optimal grasping and facilitating tasks like reaching the mid-line for self-care. While both hand and wrist function contribute to overall function, a recent study involving able-bodied subjects revealed an interesting finding: combining a robust two degree-of-freedom (DOF) wrist function (flexion/extension and rotation) with a single hand grasp is just as effective as pairing a 22-DOF intact hand with a wrist that only provides rotation.[1]

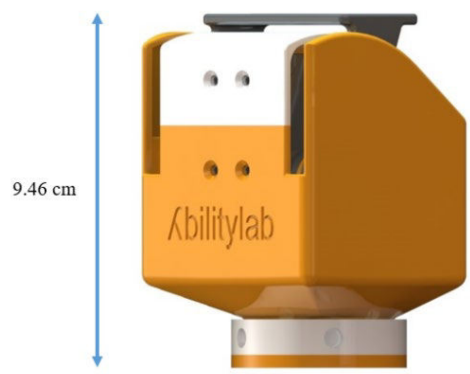
In the field of prosthetics, many multifunctional dexterous hands are now commercially available, such as the Bebionic Hand, Ability Hand, i-limb Ultra, and Taska. These devices have the potential to perform several hand grasps, but their complexity can impact their durability and make them challenging to control. Surprisingly, prosthetic wrists have seen limited evolution. Currently, there are two powered wrist rotators available from Motion Control and Ottobock. Only Motion Control markets a powered wrist flexion/extension unit. A major challenge in developing 2-DOF wrists has been creating a device that is short and lightweight. A further challenge has been controlling additional degrees of freedom using conventional amplitude-based control systems. New lightweight motors and pattern recognition–based control have emerged as potential solutions allowing for wrist rotation, flexion/extension, and hand grasp restoration.

The primary objective of this project is to evaluate the functional importance of a multifunction wrist compared to a single degree-of-freedom wrist. This was accomplished through in-laboratory testing of a custom designed wrist system with integrated wrist rotation and wrist flexion and extension. Changes in performance were assessed with multiple outcome measures that include both quantitative and qualitative testing of prosthesis control and functional performance. We hypothesize that adding a wrist flexion/extension module to a wrist rotation module and a single-DOF terminal device will provide improvements in function for transradial amputees.

METHODS

Participants were recruited with a transradial level limb absence and were fit with a custom 2DOF wrist and Ottobock Transcarpal hand (Figure 1). The custom wrist system allows for 351 degrees of rotation and 100.5 total degrees of flexion (58 degrees) and extension (42.5 degrees). For each participant, the prosthetic components were connected to a custom fabricated flexible inner socket and a fiberglass casting outer socket. When possible, an individual's home prosthesis was duplicated and modified, if needed, to allow for 8 channels of EMG. For condition

1, the wrist flexor was disabled and locked in place at a neutral position relative to the hand connection plate. For condition 2, the wrist flexor was enabled. All degrees-of-freedom were controlled using pattern recognition. The pattern recognition controller was a custom designed system with 8 channels of EMG input using an LDA classifier. All participants began with condition 1 (wrist rotation only) and then progressed to condition 2 (wrist rotation and wrist flexion) to align with how degrees-of-freedom would be added in a clinical scenario.



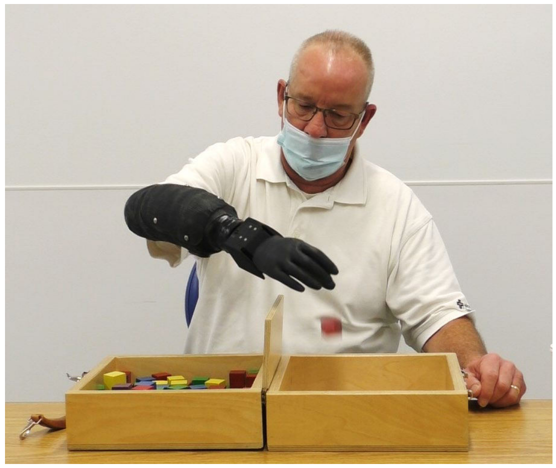


Figure 1: CAD image of wrist unit (left), participant wearing the prosthesis to complete the Box and Blocks test (right)

After participants were trained in the use of the system by an occupational therapist, they then completed outcome testing. These outcomes included the Southampton Hand Assessment Procedure (SHAP), Box and Blocks Test, Jebsen Taylor Test (total time in seconds for all tasks), Activity Measures for Upper Limb Amputees (AM-ULA), Clothespin Relocation Task (time to move 3 pins), and Assessment for Capacity of Myoelectric Control (ACMC).[2] Some participants completed a home trial with the device and repeated outcome testing before proceeding to the second condition. However, due to delays from Covid-19, not all participants completed home trials. Therefore, pre-home outcomes are presented for all participants. This study was approved by the Northwestern University IRB and all participants provided written consent.

RESULTS

Five participants, all with an amputation secondary to trauma, were recruited for this study. All participants had experience with myoelectric control but did not necessarily utilize a myoelectric prosthesis on a daily basis. Demographics are presented in Table 1.

Table 1: Participant demographics.

	Prosthetic side	**TMR**	**Primary home device at time of participation**	**Age at time of enrollment**	**Home trial after Condition 1/2**
P1	Right	N	Myo with 2-site control: Taska, passive wrist	55	Y/Y
P2	Left	Y	None: Abandon use	34	Y/N
P3	Left	N	Myo with 2-site control: Bebionic, passive wrist	28	Y/Y
P4	Right	N	Body powered: TRS Jaws	40	N/N
P5	Left	Y	Equal use of Body powered: 5x hook & Myo with Pattern recognition control: Bebionic hand and passive wrist	32	Y/N

Results of the functional outcomes are presented in Table 2. The results are the average and standard deviation for the 5 participants for pre-home outcome testing. The SHAP Index of Function is presented (higher scores indicate improved function). The Jebsen Taylor score is the total time to complete all tasks, summed and in seconds with lower scores indicating improved function. The AM-ULA is the total score with a higher value indicating a better score. Higher ACMC scores indicate improved function. The Clothespin Relocation Task result presented is the time, in seconds, to move 3 pins with 3 trials included per participant; a lower time would indicate faster performance. The Box and Blocks result is the number of blocks moved in 1 minute, with 3 trials included per person. More blocks would indicate improved performance.

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Table 2: Results of functional testing for the 2 conditions, with and without wrist flexion. Average and standard deviation shown.

	SHAP		**Jebsen**		**AM-ULA**		**ACMC**		**Clothespin**		**Box & Blocks**	
	WR`	WR & WF	WR	WR & WF	WR	WR & WF	WR	WR & WF	WR	WR & WF	WR	WR & WF
Average	39.60	35.40	269.85	268.40	13.33	13.11	55.82	51.06	23.29	23.98	10.33	10.87
Std Dev	*6.90*	*5.01*	*25.37*	*27.63*	*0.68*	*0.74*	*4.54*	*3.31*	*2.27*	*2.79*	*1.42*	*1.88*

DISCUSSION

Overall results between the two conditions, wrist rotation only and wrist rotation with wrist flexion, are very similar. Though improvements in the outcomes were expected, the increased mass, length, and control complexity of the system likely did not allow for faster performance on the timed outcomes (SHAP, Jebsen, Clothespin and Box and Blocks). Though the addition of wrist flexion may have reduced some compensatory movements, the overall score of the AM-ULA is based on the multiple factors, including speed, compensation/awkwardness, and skillfulness, which did not appear to be sensitive to the change in components.

One major limitation is that only 2 of the 5 participants were able to complete all home trials due to delays in the study from Covid-19. Participants may have had additional improvements in function with this additional time to learn to use the device in a home environment. However, despite these limitations, the addition of this degree-of-freedom also did not appear to negatively impact function.

ACKNOWLEDGEMENTS

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