

Ease of Activities of Daily Living with Conventional and Multigrip Myoelectric Hands

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ABSTRACT

Introduction: The human hand is greatly complex and makes it possible to manipulate and hold objects using many different grips, whereas the function of traditional myoelectric prosthetic hands is dramatically limited, offering only the tripod grip. Therefore, amputees use the prosthesis actively for only about 50% of activities of daily living (ADLs). The purpose of this study was to investigate whether the Michelangelo hand (Otto Bock HealthCare GmbH, Duderstadt, Germany) offering more grip modes as well as a flexible wrist improves function and reduces perceived difficulty of performing ADLs in comparison to conventional myoelectric hands.

Materials and Methods: A questionnaire that combined the validated Orthotics and Prosthetics User Survey—Upper Extremity Functional Status (OPUS-UEFS) and the Prosthetic Upper Extremity Functional Index (PUFI) was used to assess perceived difficulty and usefulness of the prosthesis in performing 23 ADLs. Patients completed this questionnaire at baseline for their existing prosthetic hand and after a minimum of 4 weeks of use of the Michelangelo hand.

Results: Sixteen male transradial amputees with an average age of 41 ± 14 years were enrolled. The mean period since amputation was 11.8 ± 16.1 years, and the mean duration of Michelangelo use was 12.4 ± 7.3 weeks. The Michelangelo hand significantly improved the ease of performing the 23 ADLs in the OPUS-UEFS from 27.0 ± 9.7 to 36.4 ± 12.7 ($p = 0.03$). The mean total score for bimanual activities improved highly significantly ($p = 0.01$) with 26.2 ± 8.1 for Michelangelo as compared with 20.0 ± 7.1 with the previous hand. Using the Michelangelo hand patients performed significantly more ADLs with “both hands together with the prosthetic hand used actively to grasp” as compared with the conventional myoelectric hands (means 9.3 ± 4.6 vs. 7.1 ± 4.1 ADLs; $p = 0.04$). In addition, the Michelangelo hand was rated as very useful for significantly more ADLs (9.1 ± 4.3 vs. 6.4 ± 4.1 ADLs; $p = 0.01$).

Conclusions: These results suggest that the Michelangelo hand offering more grip types and functional hand positions as well as a flexible wrist may be used more actively and for more ADLs. These effects seem to be promoted by a reduced perceived difficulty to perform many ADLs as Michelangelo shortens the functional gap between prosthetic and sound human hands. (*J Prosthet Orthot.* 2015;27:46–52.)

KEY INDEXING TERMS: myoelectric hand, Michelangelo hand, multiarticulating hand, prosthetic upper limb

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Disclosure: Two of the authors (Eva Pröbsting, Andreas Kannenberg) are full-time employees of Otto Bock HealthCare LP, Austin, Texas, the manufacturer of the Michelangelo hand. The rest of the authors declare no conflicts of interest.

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The hand, in conjunction with the forearm and upper arm, is the most important tool for humans, with 90% of all functions of the upper limb being supported by the hand.¹ A sensory, working, and mobility organ, the human hand consists of 27 bones, 33 muscles, and 29 joints.² It is connected to the forearm by another joint, the wrist. Its great complexity makes it possible to manipulate and hold objects using 33 different grips.³ Various attempts have been made to categorize and designate these different grips.⁴

Two basic types of grips can be distinguished—the power grip and the precision grip. The power grip is used for large or heavy objects; the precision grip is used for small or fragile objects.^{5,6}

After a transradial amputation, the function of the missing hand can be more or less well replaced by a prosthetic hand or prosthetic tools such as hooks or Greifers. The prosthetic hands available on the market have been improved considerably in recent years,^{7–9} but they are still much less functional than a sound human hand.^{7,10}

Around 80% to 90% of all transradial amputees initially decide to be fitted with a prosthetic hand,^{11,12} but they use the prosthesis actively for only about 50% of activities of daily living (ADLs).¹¹ A literature review shows that the rate of

Table 1. Demographic data on subjects with prosthesis details

Patient number	Age, years	Amputated side	Left- or right-handed	Amputated since, years	Etiology	Length of the residual limb			Previous prosthesis
						>2/3	1/3–2/3	<1/3	
1	35	Right	Left	—	Congenital deformity	X			SensorHand Speed
2	50	Right	Right	39	Trauma		X		SensorHand Speed
3	41	Left	Right	—	Congenital deformity			X	SensorHand Speed
4	40	Left	Right	—	Congenital deformity			X	SensorHand Speed
5	61	Left	Right	17	Trauma		X		SensorHand Speed
6	49	Left	Right	3	Trauma	X			SensorHand Speed
7	41	Left	Right	—	Congenital deformity	X			SensorHand Speed
8	49	Left	Right	—	Congenital deformity			X	MyoHand VariPlus Speed
9	57	Right	Right	43	Trauma		X		MyoHand VariPlus Speed
10	64	Right	Right	5	Cancer		X		SensorHand Speed body powered Hook Greifer
11	23	Left	Right	0.8	Trauma		X		Motion Control Hand
12	37	Left	Right	4	Trauma			X	SensorHand Speed
13	21	Left	Right	0.4	Trauma			X	MyoHand VariPlus Speed
14	22	Left	Right	0.7	Elective	X			DMC plus Myohand
15	44	Left	Right	—	Congenital deformity			X	SensorHand Speed
16	27	Right	Right	5	Trauma			X	

rejection of the prosthesis varies widely between 38% and 100% but shows no significant differences between passive and myoelectric or body-powered devices.¹³ However, it is known that being fitted with a prosthesis within a “golden window” of 30 days after the amputation can have a positive effect on acceptance and utilization of the prosthesis as well as on rehabilitation.¹⁴

The amputee has the options of a passive hand, an active hand controlled by a harness (body powered), or an active myoelectric hand.^{13–15} For decades, all of the hands in the latter two categories have enabled only a single movement—opening and closing the hand using the opposition grip.¹⁰ In recent years, multiarticulating hands with several joints that support various grip types have been developed and made commercially available (the i-limb from Touch Bionics, Livingston, United Kingdom; the bebionic hand from RSL Steeper, Leeds, United Kingdom; the Vincent Evolution from Vincent Systems, Weingarten, Germany; and the Michelangelo hand from Otto Bock HealthCare GmbH, Duderstadt, Germany).^{2,16} A detailed comparative technical review of the various multiarticulating prosthetic hands has been published by Belter et al.¹⁷ The extent to which these technical advances of various grip options of multiarticulating hands translate into added functionality in performing ADLs has been demonstrated in two publications^{10,18} thus far.

The purpose of this study was to investigate whether the Michelangelo hand (Otto Bock HealthCare GmbH, Duderstadt, Germany) offering more grip modes as well as a flexible wrist improves function and reduces perceived difficulty of performing ADLs as compared with conventional myoelectric hands. Because the utilization and usefulness of prosthetic hands in the daily life of amputees can be best documented by questionnaires,¹⁹ this study included a standardized survey of 16

transradial amputees on their previous prosthesis and the prosthesis with the Michelangelo hand.

METHODS

STUDY DESIGN AND PROCEDURE

Eleven prosthetic clinics in seven countries participated in this study and enrolled experienced transradial amputees. This study was conducted in accordance with the Declaration of Helsinki and the guidelines of the ethics committee of the Georg August University, Göttingen, Germany. All investigations followed the ethical and human principles of research. Written informed consent of all participants for participation and publication was obtained. The test subjects' demographic data and information on their existing prosthesis were documented and are shown in Table 1. The test subjects evaluated their previous prosthetic hand before the start of the test phase (baseline interview). The patients were then fitted with the multiarticulating Michelangelo prosthetic hand¹⁷ and trained in its use during the period from March to August 2011. The amputees used the new hand for everyday activities during a test phase of at least 4 weeks. Then, they rated Michelangelo at the end of the test phase (follow-up interview).

The survey was conducted using a standardized questionnaire. There are various validated tests for the use of an upper-limb prosthesis in everyday activities^{8,19–21}; the optimal assessment of prosthesis use can only be made using a combination of different tests.²⁰ For this reason, two validated questionnaires were combined for this study; these are the following: 1) the Orthotics and Prosthetics User Survey—Upper Extremity Functional Status (OPUS-UEFS) module and 2) two rating scales of the Prosthetic Upper Extremity Functional Index

(PUFI). The primary outcome evaluated in this study was the OPUS-UEFS with 23 activities.²² However, unlike the original version that asks a subject how easily he/she can perform an activity in general and if he/she does or does not use the prosthesis for the respective activity, the rating instructions for this study were modified to specifically investigate the perceived difficulty of activity execution with the prosthetic hand. The reason for this modification was that the present study intended to survey the functional differences between the previous terminal devices and the Michelangelo hand and not the overall adaptations to and compensations for the functional consequences of the amputation. The response categories were structured according to the original OPUS²² but analyzed using the revised rating scale as published by Burger et al.²³ on the basis of their Rasch analysis. Level 1 (“very difficult”) and level 2 (“slightly difficult”) were grouped together, resulting in a 4-point scale (0, cannot perform activity; 1, difficult; 2, easy; 3, very easy). In the analysis of the OPUS-UEFS, the sum score for all 23 activities²² and, to compare the data, for the 19 activities according to the study by Burger et al.²³ was calculated for both prostheses. In addition, we also compared the subscores for monomanual and bimanual activities between the hands. These sum scores were tested for significant differences using the Wilcoxon test in WinSTAT for MS Excel (Microsoft Corporation, Redmond, WA, USA); a significance level of $p < 0.05$ was specified. Furthermore, significance was tested for all 23 individual activities.

In addition, the OPUS was supplemented by the following two rating scales and corresponding response categories of the PUFI for each item: “How do you usually perform this activity?” and “How useful is the prosthesis for this activity?”²⁴

THE MICHELANGELO HAND

The Michelangelo hand consists of four movable fingers, a thumb that can be positioned separately by muscle signals, a finger tension plate that couples all four fingers and the thumb with the main drive, and a movable wrist joint.

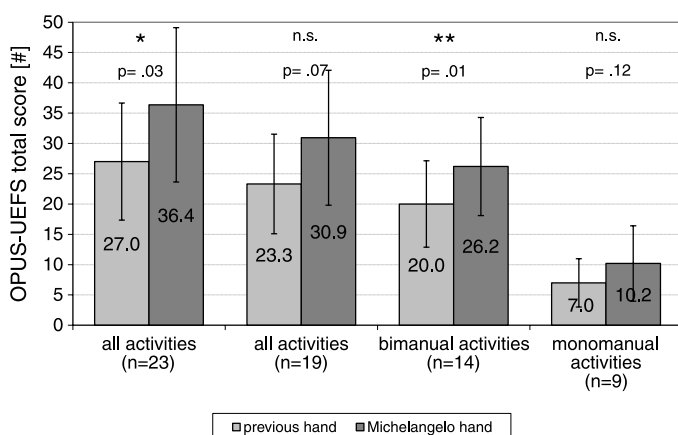


Figure 1. Mean sum score for the Orthotics and Prosthetics User Survey–Upper Extremity Functional Status (OPUS-UEFS) for all 23 activities,²² for 19 activities,²³ bimanual activities, and monomanual activities with the previous hands and the Michelangelo hand.

The thumb, index finger, and middle finger are used to develop grip strength. These three fingers are directly connected to the main drive. The full force of the main drive is thus transferred to these three fingers. The ring finger and little finger follow the other fingers passively. The hand also features a thumb drive that allows for the thumb to be myoelectrically positioned in the opposition or lateral position to the index finger. When not in use, that is, when the muscles are relaxed, the hand can be programmed to automatically assume the neutral position that corresponds with the relaxed position of a natural hand. The result is a palm with an externally rotated thumb.

The integrated wrist joint consists of two modules that support rotation and passive flexion/extension. In the rigid mode, the wrist can be locked at the desired flexion or extension angle using eight different preset positions. It also has an additional optional flexible mode so the joint can be used without fixed settings. In the flexible mode, the hand is moved against a spring resistance and then returns to the zero position of the wrist joint. In both the rigid and the flexible mode, the wrist joint can be rotated 360 degrees and locked into position at 15-degree increments.

A central control unit receives control signals from the user and assigns them to the components of the hand. Data communication is also controlled here. The unit is powered centrally from a battery with three lithium ion cells.

PATIENT SAMPLE

The study included 16 male transradial amputees. The subjects' mean age was 41 ± 14 years. Six subjects had congenital deformities of the hand, eight lost their hands due to trauma, one subject was amputated due to cancer, and another individual had an elective amputation because of a loss of hand function. The mean period since amputation was 12.8 ± 16.8 years. The mean duration of the trial fitting with the Michelangelo hand was 12.4 ± 7.3 weeks. Detailed data on the subjects are presented in Table 1.

PROSTHESES AND OCCUPATIONAL THERAPY

All subjects were fitted with a Michelangelo hand for the test phase. At study entry, the subjects used various terminal devices. Ten patients had a SensorHand Speed, three had a VariPlus Speed, one had a DMC plus (Dynamic Mode Control), and one had a MotionControl hand. Two subjects had a Greifer; one of them used it in addition to his SensorHand Speed. After Michelangelo fitting, the individuals received occupational therapy and device training according to the standards of their particular attending prosthetic clinic, thus reflecting the real-life range of prosthesis training standards across clinics and national health care systems.

RESULTS

ORTHOTICS AND PROSTHETICS USER SURVEY–UPPER EXTREMITY FUNCTIONAL STATUS

The mean sum score of the OPUS-UEFS for 23 activities was significantly ($p = 0.03$) higher with the Michelangelo hand

Table 2. Individual results of the activities of the Orthotics and Prosthetics User Survey–Upper Extremity Functional Status (OPUS-UEFS)

Activity	Mean score (SD)		<i>p</i> value	Using prosthesis, % patients	
	Previous hand	Michelangelo hand		Previous hand	Michelangelo hand
Wash face	0.2 (0.5)	1.0 (1.1)	0.04	0	13
Put toothpaste on brush	1.6 (1.2)	2.0 (1.2)	0.15	31	56
Brush/comb hair	0.3 (0.6)	0.6 (1.0)	0.31	0	13
Put on and remove T-shirt	1.6 (1.2)	1.4 (1.4)	0.72	44	38
Button shirt with front buttons	1.3 (0.9)	1.2 (1.2)	0.74	50	44
Attach end of zipper and zip jackets	1.8 (0.8)	2.0 (0.9)	0.40	94	94
Put on socks	0.7 (0.9)	1.5 (1.2)	0.03	13	31
Tie shoe laces	1.7 (1.1)	2.2 (0.9)	0.03	81	88
Drink from a paper cup	0.5 (0.7)	0.8 (1.0)	0.25	13	19
Use fork or spoon	0.9 (0.9)	1.3 (1.3)	0.23	25	19
Cut meat with knife and fork	1.5 (0.7)	2.2 (0.8)	0.03	75	81
Pour from a 12-oz can	1.4 (1.2)	1.8 (1.0)	0.45	38	56
Write name legibly	0.7 (1.0)	1.1 (1.2)	0.29	31	31
Use scissors	0.8 (1.0)	1.6 (1.3)	0.10	44	75
Open door with knob	0.6 (0.7)	0.9 (0.9)	0.27	6	13
Use a key in a lock	0.6 (1.0)	0.9 (1.1)	0.31	6	0
Carry laundry basket	2.0 (1.1)	2.7 (0.7)	0.02	75	81
Dial a touch tone phone	0.7 (0.9)	1.1 (1.1)	0.24	0	13
Use a hammer and nail	1.1 (0.9)	1.5 (1.0)	0.21	81	81
Fold a bath towel	2.1 (1.1)	2.6 (0.8)	0.07	69	88
Open an envelope	2.0 (0.8)	2.4 (0.7)	0.18	75	81
Stir in a bowl	1.7 (0.8)	2.1 (0.9)	0.21	88	94
Put on and take of prosthesis	1.3 (1.4)	1.8 (1.3)	0.11	—	—

Individual results of the activities of the OPUS-UEFS (left), the *p* values; differences in the OPUS-UEFS between the devices were significant for $p < 0.05$ (center) and information on prosthesis use for each activity (right).

(36.4 ± 12.7) than with the previous hands (27.0 ± 9.7), as shown in Figure 1. The mean sum score for bimanual activities improved highly significantly ($p = 0.01$) with 26.2 ± 8.1 for Michelangelo as compared with 20.0 ± 7.1 with the previous hands, whereas no difference was found for monomanual activities. The mean sum score of the OPUS-UEFS for 19 activities showed a trend ($p = 0.07$) in favor of the Michelangelo hand (30.9 ± 11.1) as compared with the previous hands (23.3 ± 8.2). On average, improvement was observed when using the Michelangelo hand in 20 of the 23 individual activities; this improvement was significant in five activities (“wash face,” “put on socks,” “tie shoe laces,” “cut meat with knife and fork,” and “carry laundry basket”). The subjects described two activities as being easier with their previous hand, namely, “put on and remove T-shirt” and “button shirt with front buttons”; however, these differences did not attain statistical significance, as presented in Table 2.

ADDITIONAL RATING SCALES OF THE PROSTHETIC UPPER EXTREMITY FUNCTIONAL INDEX

The Michelangelo hand was described as clearly more useful than the previous hands. On average, the Michelangelo hand was reported to be very useful for 9.1 ± 4.3 activities, as compared with only 6.4 ± 4.1 activities for the previous devices ($p = 0.01$), as shown in more detail in Figure 2.

There were also clear differences in how the conventional and multiarticulating hands were used for the activities (Figure 3). The response “both arms together with the prosthetic hand used actively to grasp” was given for significantly ($p = 0.04$) more activities with the Michelangelo hand (9.3 ± 4.6) than with the previous hands (7.1 ± 4.1). However, for the other responses

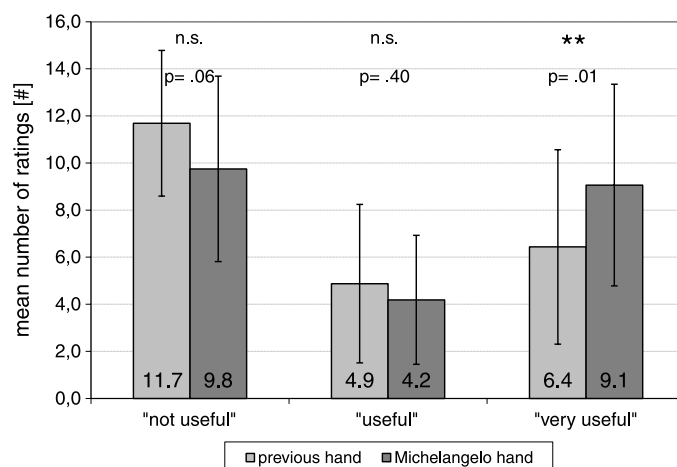


Figure 2. Mean number of responses regarding the usefulness of the prosthesis for the 23 activities of the Orthotics and Prosthetics User Survey–Upper Extremity Functional Status (OPUS-UEFS).

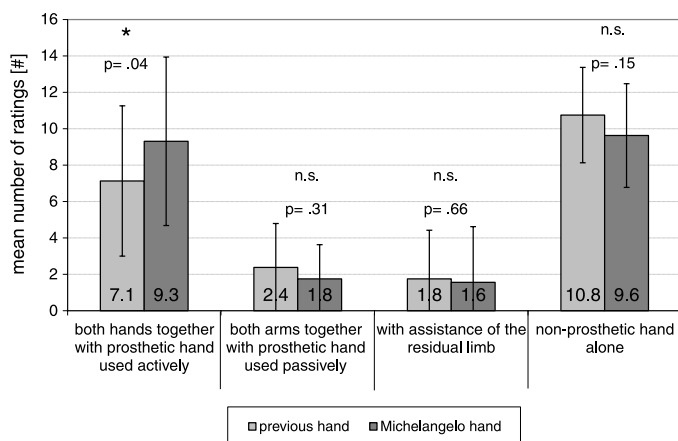


Figure 3. Mean number of responses on the way of performing the 23 activities of the Orthotics and Prosthetics User Survey–Upper Extremity Functional Status (OPUS-UEFS).

“both arms together with the prosthetic hand used passively to position or stabilize an object on surface or against another object,” “with assistance of the residual limb,” and “nonprosthetic hand alone,” only minimal differences between the prosthetic hands were seen. The two response options “with some help from another person” and “other way” were almost never used.

If the response options “both arms together with the prosthetic hand used actively to grasp” and “both arms together with the prosthetic hand used passively to position or stabilize an object on surface or against another object” are combined to “using the prosthesis,” the mean number of activities in which the prosthesis was used was significantly greater ($p = 0.04$; 11.1 ± 4.2 activities) for the Michelangelo hand than for the previous prostheses (9.5 ± 3.7 activities).

Table 2 shows the percentage of subjects who use the prostheses for each of the individual activities. The prosthesis with the Michelangelo hand was used more often in 15 activities, the previous hands in only four activities (“put on and remove T-Shirt,” “button shirt with front buttons,” “use fork or spoon,” “use a key in a lock”), and no difference was found in three activities (“attach end of zipper and zip jackets,” “write name legibly,” “use a hammer and nail”).

DISCUSSION

The primary outcome measure of this study was the OPUS-UEFS. The mean sum score for all 23 activities was significantly higher with the Michelangelo hand, indicating that this hand clearly simplifies ADLs. To allow for a comparison with data in the literature, the mean sum score was also calculated for 19 activities.^{10,23} Only a trend toward improvement was seen here with the Michelangelo hand; at $p = 0.07$, the level of significance was almost reached. Van der Niet Otr et al.¹⁰ also used the OPUS-UEFS among other measures to test the differences between the i-limb and the DMC plus hand in one patient and found no significant difference. However, in this study, the difference was clearly lower than in the present one.

Significantly greater ease of execution was observed in 5 and a trend in further 15 ADLs when the Michelangelo hand was used. However, for 2 of the 23 activities, there was a trend to easier performance with the previous terminal devices that did not attain significance. For “put on and remove T-shirt,” this can be explained by the different positions of the hands when no muscle activity is present. Conventional hands are closed, whereas the Michelangelo hand takes the neutral position of a relaxed human hand with the thumb slightly abducted. Although appearance is more natural, the thumb may get caught when putting on or removing a T-shirt, making this activity more difficult. Users can close the Michelangelo hand for this activity, but they will need training to do so intuitively. The second activity, “button shirt with front buttons,” requires a great deal of training anyway, which the subjects presumably did not have with the Michelangelo hand in this relatively short test phase. The two other activities that involve getting dressed, “put on socks” and “tie shoe laces,” were perceived to be significantly easier with the Michelangelo hand. Simplifying getting dressed gives an amputee more independence and is desired by amputees as shown by the results of an internet survey.²⁵ It is known that aside from getting dressed, activities that involve personal hygiene are very complicated to perform with an upper-limb prosthesis,²⁶ although it would be very beneficial for amputees to be able to perform them more easily with their prosthesis.²⁵ Therefore, the more frequent use and significant simplification of the activities “wash face” is another important benefit of the Michelangelo hand over the previously used hands.

Although, on average, most of all activities were easier for the subjects with the Michelangelo hand, the results for many activities were still clearly below the maximum rating of 3 (very easy) that individuals with two sound hands would choose. This demonstrates that despite the impressive advances in prosthetic hand technology, the functionality of the sound human hand is still unrivaled.

The results on the use of the prosthesis for the various activities are comparable with the results of Burger et al.²³ In this study, also fewer subjects used either prosthesis for monomanual activities (“brush/comb hair,” “open door with knob,” “use fork or spoon,” “drink from a paper cup,” “write name legibly,” “use a key in a lock,” “dial a touchtone phone,” and “pour from a 12-oz can”) than for bimanual activities. It is noteworthy, however, that in the present study, on average, patients used both types of prosthetic hands more frequently than in the study of Burger et al.²³ One reason for that could be the higher amputation level in 14 of the 61 subjects in the Burger et al.²³ study.

The separation of monomanual and bimanual activities also seems to be useful for interpreting the results of perceived difficulty of the activities. In the present study, the subjects showed a clear reduction in the difficulty of bimanual activities with the Michelangelo hand that was far more pronounced than in the sum score of all activities. Activities that can be performed with only one hand are typically not performed with the prosthetic hand but with the sound hand.^{14,23} These activities are therefore not made easier by a more functional prosthetic hand, which is

confirmed by the insignificant differences in the OPUS-UEFS subscore for monomanual activities.

Burger et al.²³ found a difference between the results of transradial amputees whose dominant side and those whose nondominant hand was amputated. This difference could not be confirmed in the present study; however, the number of subjects with an amputation of the dominant hand was very low, with $n = 4$.

The results for the rating scales of the PUFU cannot be compared with data in the literature because the PUFU has been validated only for activities of children and adolescents,^{20,21,24} who generally have other demands for a prosthesis and use it differently than adults.²⁵ It was nevertheless very useful to add these questions to the OPUS-UEFS. The results make it clear that the more functional prosthesis with the Michelangelo hand is found to be very useful for significantly more activities and used more frequently not only passively but actively for grasping objects. This active use of the prosthesis not only makes everyday life easier, it also gives the amputee a more natural appearance overall. This is very important for upper-limb amputees, and the improved aesthetic appearance may increase the acceptance of the prosthesis.^{26–28}

With seven different hand positions and an integrated movable wrist joint, the Michelangelo hand gives amputees many new options for using the prosthesis. In order for the amputee to utilize the functions in everyday activities and benefit from them, he or she needs a great deal of practice and occupational therapy. Even after a mean test phase of only 12.7 ± 7.3 weeks without standardized occupational therapy, more frequent and active use of the prosthetic hand and significant improvements in bimanual activities were found with the Michelangelo hand as compared with conventional myoelectric hands. We can only assume that there would have been further improvements after specific training and a longer accommodation phase.

CONCLUSIONS

In conclusion, with the use of the Michelangelo hand, many ADLs were perceived to be easier to perform, resulting in a more active use of the prosthetic hand and a trend to reduce the primarily passive use of the prosthesis. Further research with performance-based outcome measures is encouraged to corroborate these self-reported findings.

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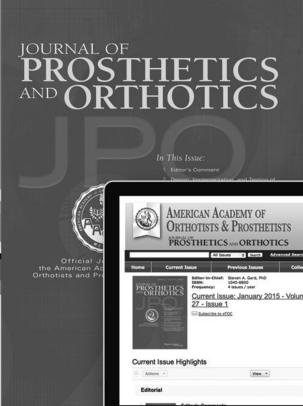
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