THE COMPARISON OF FUNCTION AND USEFULNESS OF VOLUNTARY CLOSING AND VOLUNTARY OPENING BODY-POWERED PROSTHESES

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ABSTRACT

A comparison of functionality of the voluntary opening (VO) terminal device and the voluntary closing (VC) terminal device was performed using body-powered prostheses simulator on 52 non-amputee adults. We compared The Southampton Hand Assessment Procedure (SHAP) score and time required to complete SHAP's 26 tasks. The results show that the VC terminal device is easier to operate than the VO terminal device, when strong gripping force and quick reaction time is required.

BACKGROUND

Voluntary opening (VO) terminal device is often selected for body-powered prosthesis. Yet, there are tasks where voluntary closing (VC) terminal device are known to be more useable by experience. There are studies comparing the pinch force and cable efficiency of the hands and hooks of VO/VC terminal deices[1,2]. However, these research do not compare the actual ease of use of the VO and VC terminal device in daily living activities. There is also a report which discusses the VOC type, that is capable of switching between VO and VC, is most efficient[3], although the actual situation is not clear and further research is need. We believe the necessity to distinguish the characteristics of the VO and VC for selecting the best terminal device for the amputee's daily activities when prescribing body-powered prosthesis. This research evaluates and compares the VO and VC terminal device with a body-powered prosthesis simulator donned on the left arm by non-amputee subjects.

OBJECT AND METHOD

This study was approved by the Ethics Committee of the Faculty of Medicine of the University of Tokyo. The participants were non-amputee adults (n=52, 26 males and 26 females), average age was 30.6 years, all right-handed (Edinburgh dominant hand test was more than 50 points). Written consent was obtained from all participants. The Southampton Hand Assessment Procedure (SHAP) was performed with VOC terminal device (infinite Equilux) attached to the body-powered prosthesis simulator, and with the participants' left sound hand. SHAP is an upper limb function test developed in the UK, in 2002. It consists of 2 tests: a12-item test for daily movements with different shapes (e.g. spheres and cylinders) and weights, and a 14-item two-handed motion test. SHAP is an assessment tool

that evaluates the time required to perform each task and automatically calculates the score using its own formula by inputting it into the SHAP Web program. In addition to the total score, scores for each of the six hand movement patterns (Tip, Lateral, Tripod, Spherical, Power, and Extension) are calculated as functionality profiles. The lowest possible score is 0, while the highest is 100 + α, and the cut-off score of a normal person is 95.

All subjects had no experience using body-powered prosthesis simulator or SHAP. The subjects were divided into two groups: the VO group which performed the test with the VO terminal device and the VC group with the VC terminal device. The two groups were randomized by stratification equally so that there was no difference in the number, age, and gender. The SHAP scores and the time required to perform each task was compared between the two groups. In addition, cable efficiencies were measured when using the body-powered prosthesis simulator with each setting. The SHAP scores, task perform time, and Edinburgh dominant test score were compared by Wilcoxon signed rank test. Statistical analysis was performed using JMP® Pro 14.2.0 (SAS Institute Japan) and $p < 0.05$ was considered significant.

RESULT

VO group was 26 people, 13 males and 13 females (average age: 30.3 years, average Edinburgh dominant test points: 97.1) and VC group was 26 people, 13 males and 13 females (average age: 30.9 years, average Edinburgh dominant test points: 95.2). There were no differences between the two groups in average score of the Edinburgh dominant hand test ($p=0.23$).

The cable efficiency was 48.8% for the VO and 50.6% for the VC. The average score of SHAP with the participants' left hand was 97.2 points (ranging from 93 to 103 points), and there was no difference between the two groups (VO group average 97.3 points, VC group average 97.2 points | $p=0.75$). Table 1 shows the total score of SHAP and the scores of the six hand movement patterns. There was no significant difference between the two groups in the SHAP total score ($p=0.20$). However, for the extension, the score was significantly higher in the VC group: average of 36.8 points in the VO group and average of 42.9 points in the VC group ($p =0.005$). For all six movement patterns, the VO group's average score did not exceed that of the VC group.

Table 2 shows the time required to perform each SHAP task. When comparing the time, the VC group was significantly faster than the VO group in the three tasks: Heavy Power (VO group 9.7 seconds, VC group 8.4 seconds, $p=0.049$), Heavy Extension (VO group 8.9 seconds, VC group 7.1 seconds | $p=0.04$), and Cutting (VO group 158.9 seconds, VC group 89.6 seconds | $p<0.005$). In addition, in 19 of the 26 tasks, the average time required to perform the task were shorter in the VC group than of the VO group, including those with no significant difference.

DISCUSSION

The SHAP task with Power and Extension task is conducted handling light and heavy object of the same shape. In both Power and Extension task, there was no significant difference in the handling light objects. However there was significant difference in handling heavy objects, and was faster in the VC group. The cutting task involves holding a knife in the terminal device and pressing into the clay, which also requires a strong grip. The significant difference between the groups suggests that the VC type body-powered prosthesis is particularly useful for tasks required to generate high grip strength.

Regarding the time required to accomplish each task, the VC type was faster to grasp the object. The initial opening movement of the hook before grasping the object in the VO type makes it slower to accomplish the task.

The experimental results of VC type with higher score and shorter time than VO type for tasks that require strong gripping force or that require quick operation indicate that VC terminal device can be prescribed when the amputee is focused on these tasks in daily life, recreation, and occupation.

There are limitations to this study. The participants of this study are non-amputees, and it was the first time for all the participants to operate the body-powered prosthesis. Future studies should make efforts to measure the amputees who use the body-powered prostheses for daily use.

CONCLUSION

The aim of this study was to understand which prosthetic tool is more appropriate based on movement types and the needs of patients and prescribe a prosthesis that is easier to use the VC type moves significantly faster according to patient's lifestyle.

Table 1 : SHAP scores

	Six patterns Score						Total Score
	Sperical	Tripod	Power	Lateral	Tip	Extension	
VC	43.92	23.84	37.5	47.34	31.84	49.07	46.53
VO	40.57	20.96	35.11	44.03	26.84	36.84	42
p	0.26	0.23	0.29	0.49	0.29	0.0051*	0.2

* : p<0.05 ** : p<0.005

Table 2 : Time spend on each SHAP task

Task	Abstract Object - Lightweight						Abstract Object - Heavyweight					
	Spherical	Tripod	Power	Lateral	Tip	Extension	Spherical	Tripod	Power	Lateral	Tip	Extension
VC	6.25	12.2	5.78	9.47	11.77	7.3	12.47	7.3	8.47	9.02	7.65	7.18
VO	7.61	9.3	6.39	10.74	13.68	19	9.38	9.2	9.71	8.99	13.15	8.95
p	0.14	0.99	0.48	0.8	0.43	0.059	0.66	0.29	0.049*	0.99	0.35	0.041*

Task	Activities of Daily Living													
	Coins	Button Board	Cutting	Page Tuning	Jar Lid	Jug Pouring	Carton Pouring	Full Jar	Empty Tin	Tray Lift	Key	Zip	Screwdriver	Door Handle
VC	46.35	38.57	89.62	10.88	18.51	24.61	23.51	10.07	7.58	7.96	4.81	16.32	22.51	5.31
VO	51.86	45.22	158.99	11.99	17.89	31.79	24.71	59.97	8	8.67	5.04	11.32	18.11	4.98
p	0.11	0.18	0.0002**	0.1	0.85	0.19	0.21	0.42	0.6	0.27	0.26	0.63	0.54	0.46

* : p<0.05 ** : p<0.005

REFERENCES

[1] Smit G, B. Dick H, "Efficiency of voluntary closing hand and hook prostheses," Prosthet Orthot Int, vol. 34(4), pp. 411-427, 2010.

[2] Gerwin Smit, Raoul M. Bongers, Corry K. Van der Sluis, Dick H. Plettenburg, "Efficiency of voluntary opening hand and hook prosthetic devices: 24 years of development?" J Rehabil Res Dev. vol. 49(4), pp. 524-534, 2012.

[3] Jon W. Sensinger, James Lipsey, Ashley Thomas, Kristi Turner. "Design and evaluation of voluntary opening and voluntary closing prosthetic terminal device," J Rehabil Res Dev. vol. 52(1), pp. 63-76, 2015.