# Developing and Testing of an Upper Limb Exoskeleton for Stroke Patients

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## INTRODUCTION

Stroke has a large impact on disability and loss of motor function[1]. It can cause the affected upper limb to become spastic with a predominantly flexor tone. Stroke patients have shown improvements in hand mobility through sensorimotor arm therapy[2]. However, therapy can be expensive, and many patients still lack function in their affected hand when rehabilitation is finished[3]. Wearable devices, such as exoskeletons are useful in that they offer the ability for patients to regain mobility in their own environment[2]. The upper limb exoskeletons are designed to interact independently with the user while assisting and promoting movement of the affected hand. Our inexpensive and simple exoskeleton design is produced on a low-cost 3D printer, and allows for patients to have access outside of the lab. It is important for this exoskeleton to not only be easily accessible, but effective and useful. Traditional definitions of usability incorporate effectiveness, efficiency, and satisfaction of the user with the product. In the context of stroke survivors, the exoskeleton should be able to assist the user in extending their affected hand and allowing for flexion to grasp an object.

**Purpose:** To determine the functional outcomes of stroke patients using their non-preferred hand with and without a 3D printed passive exoskeleton compared to controls.

**Hypothesis:** The exoskeleton will increase the function of the stroke patient's affected hand and the usability questionnaire scores will be associated with improvement in the functional test results.

## METHODS
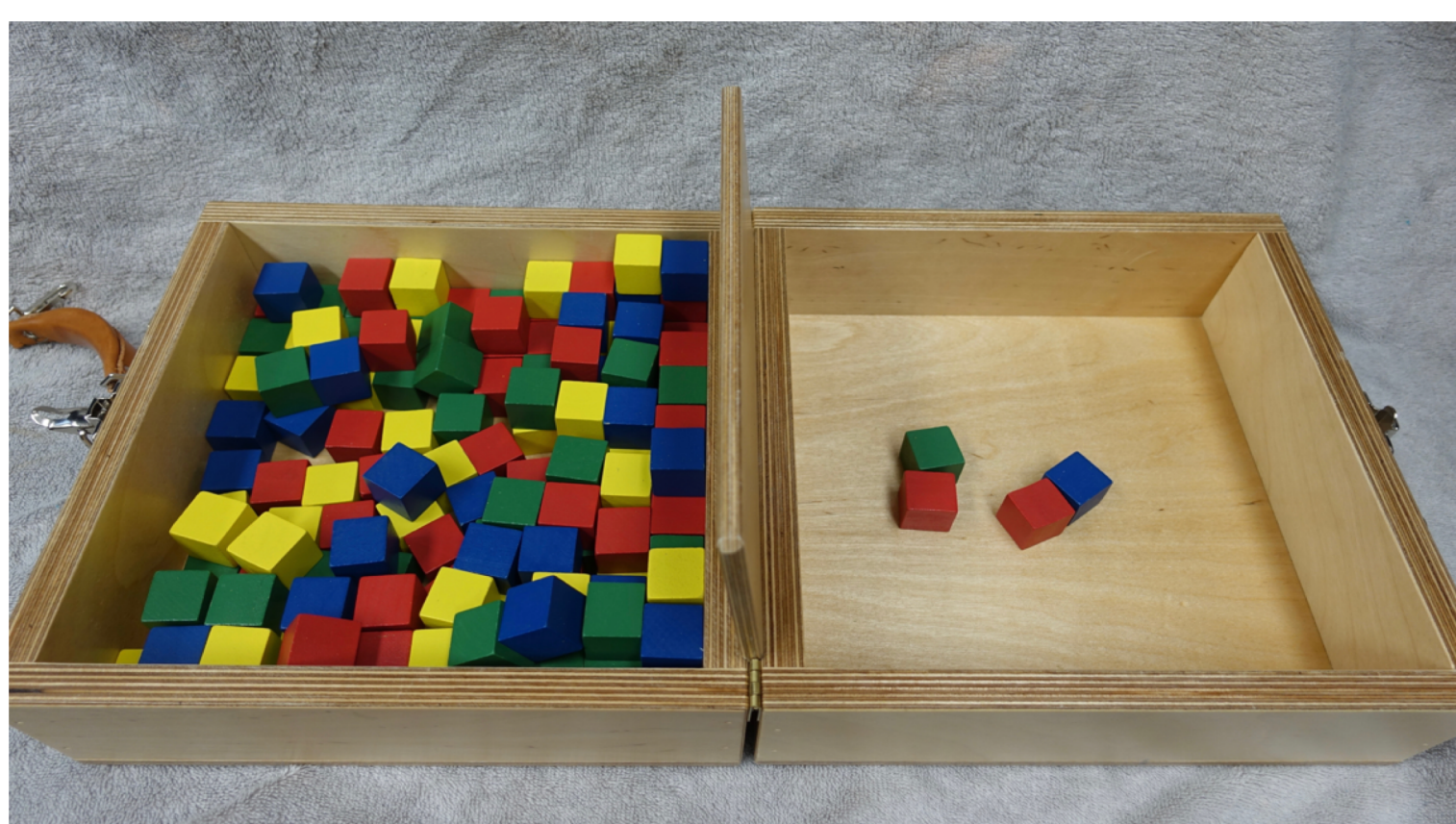


**Subjects:**
- 5 participants with stroke with impairments at least 6-months post stroke
- 5 age and sex matched healthy controls

**Procedure:**
- Exoskeleton devices were custom scaled and fitted to each subject with stroke
- Three box and block trials were each performed with the preferred hand, non-preferred hand, and non-preferred hand with the exoskeleton
- Two usability questionnaires, the System Usability Scale (SUS) and the Quebec User Evaluation of Satisfaction with assistive Technology (QUEST), were given to the subjects after testing of the exoskeleton
- Separate two-way repeated measures ANOVAs [2 x 2; exoskeleton (with versus without exoskeleton) x group (stroke versus control)] were performed to analyze the effects of using an exoskeleton in stroke and control groups
- A p-value of ≤ 0.05 was considered statistically significant for all comparisons

## RESULTS



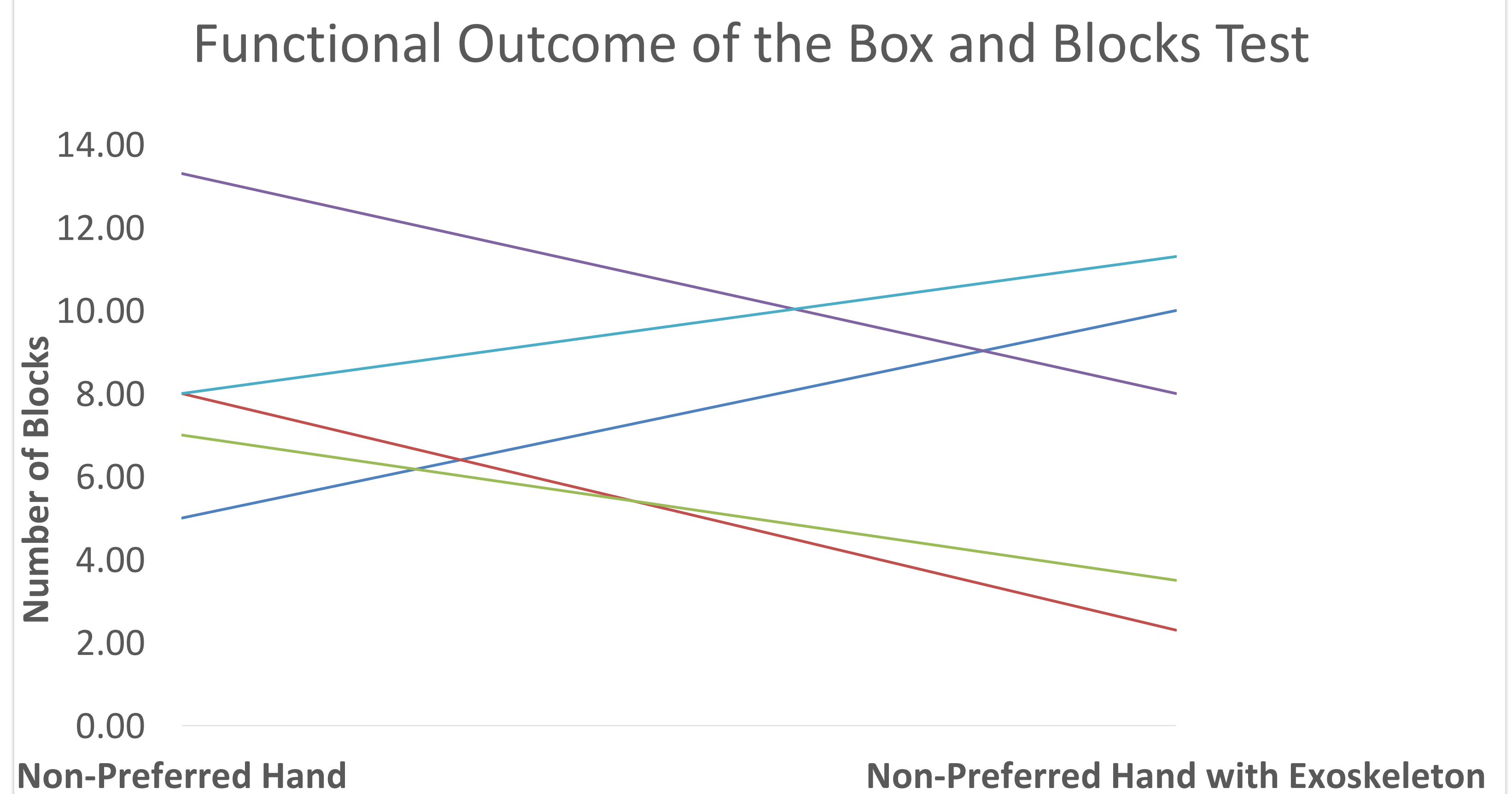Functional Outcome of the Box and Blocks Test

FIGURE 1. The differences for stroke patients in not-using the exoskeleton with their non-preferred hand (left) compared to using the exoskeleton with their non-preferred hand (right)

- For the Box and Block test (Figure 1) there was an interaction [$F(1,4) = 41.60$; $p = .003$, $\eta p^2 = 0.912$] with an observed power of 0.996
- Decomposing the model, a dependent t-test ($p = 0.004$) showed the stroke subject's preferred hand moved more blocks than the stroke subject's non-preferred hand
- The exoskeleton received an average QUEST score of $4.23 \pm 0.26$ out of a maximum score of 5 and SUS score of $79.50 \pm 15.45$ out of 100

## DISCUSSION

- The mean showed no improvement in function with the exoskeleton, but two subjects were able to increase functional improvement with the exoskeleton
- While the exoskeleton did not help with performance, the overall usability scores it received can be interpreted as "good" and "quite satisfied"
- This was the first time the subjects used the exoskeleton and a follow-up study would be beneficial to evaluate if any learning effects occurred

## CONCLUSION

The present study showed that the passive exoskeleton developed did not improve function for the stroke patients. However, the exoskeleton was able to assist two of the five subjects. Due to the differences and variation seen in impairments with stroke, the exoskeleton has shown it can be useful in individual cases.

**Future Work:** The exoskeleton will continue to be tested on new subjects and evaluating how stroke subjects' functional performance changes through prolonged use with the exoskeleton will be tested as well.

## REFERENCES

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2. Oujamaa L, et al. *Ann Phys Rehabil Med* **52,** 269-293, 2009.
3. Duncan PW, et al. *Stroke* **34,** 2173-80, 2003