

A NOVEL ROBOTIC DEVICE WITH HAPTIC FEEDBACK FOR LOWER LIMB REHABILITATION

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INTRODUCTION

After a stroke, many individuals have difficulty producing symmetric forces with their limbs. Several rehabilitation devices currently use visual biofeedback in attempts to increase this symmetry, but studies have shown only small changes in function when compared to no feedback controls [1]. A novel alternative is to use force-sensing feedback, or haptics, for rehabilitation. This technique uses computer controlled force feedback and has been suggested as a means to improve coordinated bilateral movements in the upper limbs of stroke subjects [2]. We developed a lower limb robotic device that uses haptics to investigate motor learning after stroke. In haptic feedback mode, subjects perform lower limb extensions while computer control increases resistance proportional to lower limb force asymmetry. We propose that practice with this form of direct haptic feedback will promote improved lower limb symmetry during leg extensions.

METHODS

We modified a commercially available exercise machine (Plyo-Sled, Lifestyle Sports) by adding a computer controlled electrical motor for providing resistance (Kollmorgen MT706C1-R1C1 Goldline XT Servomotor) (Figure 1). Subjects lie supine on a sled with rollers and place their feet on a vertical footplate to perform lower limb extensions. The motor affects sled movement through a rack and pinion attachment. Computer software (RT-Lab Solo, Opal-RT Technologies) controls the real-time processor to determine motor resistance. We attached a force platform (Model OR6-7MA, AMTI) to the footplate to capture center of pressure during lower limb extensions. From center of pressure data we can discern the relative symmetry between the right and left foot forces. Safety measures include an emergency stop button and electrical and mechanical stops.

In haptic feedback mode the computer controls resistance based on center of pressure from the force platform. If foot forces are equal (i.e., the subject's center of pressure remains directly in between his/her feet), the motor resistance will stay at baseline levels. If foot forces are unequal (i.e., the subject's center of pressure moves away from the center line and towards one of the feet), the computer will increase the motor resistance above baseline levels. This controller provides immediate force feedback of the amount of relative symmetry in the lower limbs. The resistance is proportional to the amount of asymmetry of the subject's foot forces. Feedback in this mode includes person-in-the-loop, where the subject can perceive increases and decreases in resistance and adjust their foot forces accordingly. If stroke subjects rely more on their non-paretic limb, they will perceive the increase in resistance and presumably increase force in their paretic limb (or decrease force in their non-paretic limb).

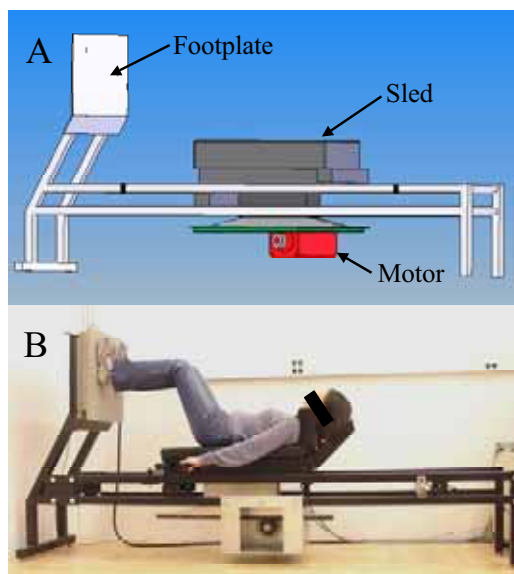


Figure 1. (a) Computer renderings of the robotic device. (b) Robotic device in use on a healthy subject.

Three healthy subjects performed leg extensions on the robotic device. Each subject performed 20 repetitions at a frequency of 0.5 Hz under two conditions; a) against baseline resistance of ~50% body weight, and b) in haptic feedback mode where the resistance was increased above baseline in proportion to the asymmetry in lower limb forces. We measured root mean square (RMS) of center of pressure excursion over the last 10 repetitions. We hypothesized that the center of pressure excursion (measure of symmetry between lower limbs) would decrease in haptic feedback mode compared to the condition with constant resistance.

RESULTS AND DISCUSSION

While providing haptic feedback to subjects, we are able to produce variable resistances up to 1200 N. Our results showed that while performing leg extensions against a constant resistance, the center of pressure excursion RMS was 3.1 ± 0.4 cm. While subjects performed leg extensions in haptic feedback mode, their center of pressure excursion RMS was 2.2 ± 0.4 cm. These results support our hypothesis and provide a basis for further testing on the robotic device in stroke subjects.

REFERENCES

1. Geiger RA, et al.. *Phys Ther* **81**, 995-1005, 2001.
2. Johnson MJ, et al.. *Robotica* **21**, 13-23, 2003.

ACKNOWLEDGEMENTS

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