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Wrist range of motion and motion frequency during toy and game play with a joint-specific controller specially designed to provide neuromuscular therapy: A proof of concept study in typically developing children

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ABSTRACT

Upper extremities affected by hemiplegic cerebral palsy (CP) and other neuromuscular disorders have been demonstrated to benefit from therapy, and the greater the duration of the therapy, the greater the benefit. A great motivator for participating in and extending the duration of therapy with children is play. Our focus is on active motion therapy of the wrist and forearm. In this study we examine the wrist motions associated with playing with two toys and three computer games controlled by a specially-designed play controller. Twenty children (ages 5–11) with no diagnosis of a muscular disorder were recruited. The play controller was fitted to the wrist and forearm of each child and used to measure and log wrist flexion and extension. Play activity and enjoyment were quantified by average wrist range of motion (ROM), motion frequency measures, and a discrete visual scale. We found significant differences in the average wrist ROM and motion frequency among the toys and games, yet there were no differences in the level of enjoyment across all toys and games, which was high. These findings indicate which toys and games may elicit the greater number of goal-directed movements, and lay the foundation for our long-term goal to develop and evaluate innovative motion-specific play controllers that are engaging rehabilitative devices for enhancing therapy and promoting neural plasticity and functional recovery in children with CP.

1. Introduction

The prevalence of cerebral palsy (CP) has risen in the last 40 years and is now estimated at approximately 3 out of every 1000 children in the US (Boyle et al., 1994; Murphy et al., 1993; Odding et al., 2006). Although there is a wide range of presentations, the upper extremity function is commonly affected, and often more pronounced than the lower limb (Arner et al., 2008; Makki et al., 2014; Wiklund and Uvebrant, 1991). Wrist extensors/flexors and forearm supinator/pronator muscles are profoundly affected in most children with hemiparetic CP and are the major target of neuromuscular therapy efforts to restore useful hand functions (Wilton, 2003).

Therapy approaches vary widely, including intramuscular injections of botulinum toxin type A (Pfeifer et al., 2014), occupational/physical therapy (Elliott et al., 2011; Mayston, 2005, 2001; Wilton, 2003), various forms of constraint-induced movement therapy (Brady and Garcia, 2009; Eliasson et al., 2005; Taub et al., 2007), and robotic therapy (Fasoli et al., 2008; Frascarelli et al., 2009). While there are benefits and trade-offs among these therapies, one overriding principal is that more therapy leads to a better outcome (Damiano, 2006). A meta-analysis of 42 studies suggested that meaningful clinical outcomes may be correlated more with the dose of therapy than the specific treatment approach (Sakzewski et al., 2014). Additionally, there was strong evidence that goal-driven therapy programs – those that involved tasks motivated by achieving individualized objectives – were

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more effective than standard care in improving upper limb and individualized outcomes (Sakzewski et al., 2014).

Our approach was to develop a goal-directed therapy that is joint specific. The joint specific requirement stemmed from our observation that while whole-body exercise, facilitated with systems such as the Ninetendo Wii (Deutsch et al., 2008; Saposnik et al., 2010), has clear benefits, repetitive targeted therapy of specific muscle groups, especially in the hand and wrist, is essential in all stages of a rehabilitation program (Oujamaa et al., 2009). To maximize the dose of intervention, we turned to play as a motivator. Accordingly, we designed a toy and game play controller that requires specific joint movements to trigger play events. In its present configuration, the controller enables play with remote controlled toys and computer games using wrist extension and flexion. This approach could provide inexpensive home-based therapy to supplement institutional PT/OT, thus maximizing the dose of therapy received.

Engagement through play is crucial to maximizing the dose of intervention. Therefore, identifying what kinds of toys and games are most engaging and which elicit the greatest number of goal-directed movements with the controller is particularly important for our approach. As a first step, we sought to examine these factors in a control population of children with no diagnosis of a neuromuscular disorder. The aim of this study was to evaluate play activity recorded by the controller for two toys and three computer games. We sought to determine if play activity, quantified by range of motion (ROM) and motion frequencies, differed among specific toys and games. We also sought to determine if the child's feedback from a discrete visual scale (DVS) questionnaire of fun and difficulty of play would correlate with measures of play activity.

2. Methods

2.1. Subjects

With IRB approval, children ($n=20$, 15 male, 5 female, 5–11 years, 19 right handed, 1 left handed) were recruited to participate in the study. Eligibility requirements specified that the children have the cognitive ability to follow instructions and no limitations of upper extremity function. The mean (1SD) active wrist ROM for these children was 137°(12°). All children participated in a structured in-clinic play session, during which they played with 4 of 5 different toys and computer games for approximately 5 min each. The order of the toys and games was randomized prior to subject arrival. The sessions were conducted in designated rooms with ample floor space for playing with the remote controlled toys, and a table for a laptop computer that contained the games.

2.2. Device

A specially designed play controller was used to interface wirelessly with the toys and games, to provide programmable thresholds for play ROM, and to log data of wrist motion during play (Fig. 1a) (Crisco et al., 2015). The play controller was designed to accommodate children of various ages and levels of contractures among children with CP. The controller (approximately 185 g) is composed of four main components: a removable and customizable foam handle, plastic wrist hinge, soft fabric forearm cuff, and electronics closure. The handle is composed of closed-cell foam tubing (1" diam.) wrapped over a malleable aluminum alloy wire (0.14" diam.) connected to the wrist hinge. The length of the foam and the length and shape of the removable wire are readily customized to fit each child's hand and wrist. The single axis wrist hinge is 3D-printed ABS plastic (25 mm diameter) and houses a potentiometer (10 kΩ linear taper, 300 ± 5°) to measure wrist flexion/extension motion. The wrist hinge is rigidly attached to a thin sheet of aluminum that is embedded within the fabric forearm cuff. The fabric for the forearm cuff and two straps is breathable, open-cell foam bonded to a smooth nylon tricot on one side and a high-nap fabric on the other side to accommodate hook-and-loop fasteners (AirFlex, Eastex Products Inc., Holbrook, MA). An additional strap assists in securing the child's hand to the foam handle grip. The electronics of the controller are encased within a 3D-printed ABS plastic shell (82 mm × 75 mm × 34 mm, 55 g) and attached to the forearm cuff with a hook-

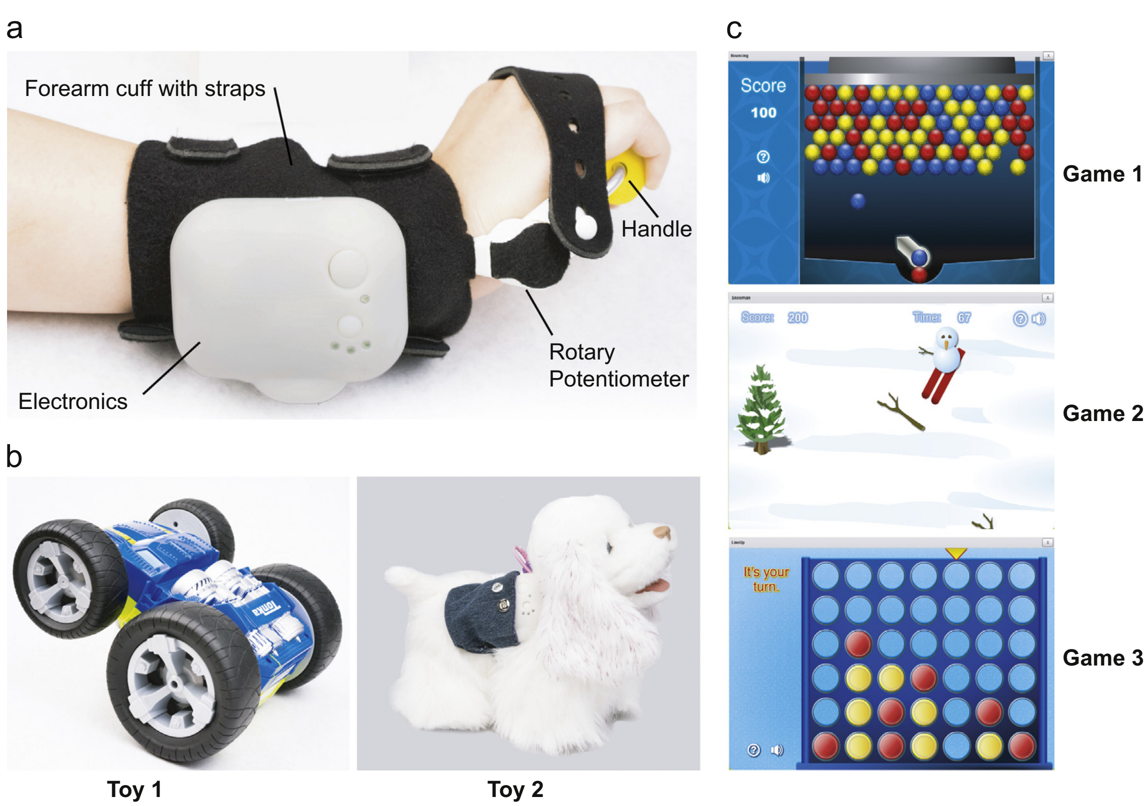

Fig. 1. Controller, remote controlled toys, and computer games. (a) Specially designed play controller used to wirelessly control toys and games. A potentiometer in-line with the flexion–extension axis records wrist motion. Wrist position thresholds to trigger play are set using buttons on the electronics case. (b) Remote controlled toys: BounceBack Racer® (Toy 1) and GoGo® (Toy 2). (c) Computer games: Bouncing Balls® (Game 1), Snowman® (Game 2), and Lineup® (Game 3).