Feasibility, Motivation, and Selective Motor Control: Virtual Reality Compared to Conventional Home Exercise in Children with Cerebral Palsy

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ABSTRACT

Children with cerebral palsy (CP) have difficulty controlling and coordinating voluntary muscle, which results in poor selective control of muscle activity. Children with spastic CP completed ankle selective motor control exercises using a virtual reality (VR) exercise system and conventional (Conv) exercises. Ankle movements were recorded with an electromyograph. Children and their parents were asked to comment on their interest in the exercise programs. Greater fun and enjoyment were expressed during the VR exercises. Children completed more repetitions of the Conv exercises, but the range of motion and hold time in the stretched position were greater during VR exercises. These data suggest that using VR to elicit or guide exercise may improve exercise compliance and enhance exercise effectiveness.

INTRODUCTION

Cerebral palsy (CP), a non-progressive but not unchanging disorder of movement and/or posture due to an insult or anomaly of the developing brain, affects up to one in three premature babies, and over 50,000 Canadians have CP.1 CP is classified based on how much of what parts of the body are affected, as well as by the movement anomaly. The degree of severity varies greatly, and each case is often described as mild, moderate or severe.2

With CP, the inability to control and coordinate voluntary muscle results in poor selective control of muscle activity. The “orderly phasing in and out of muscle activation, co-activation of muscles with similar biomechanical functions, and limited co-activation of antagonists during phasic or free movement”3 is disrupted and leads to coordination, balance, and ambulation deficits. Specifically, the child with CP cannot appropriately contract the tibialis anterior (TA) muscle, creating functional problems such as the inability to achieve heel strike during ambulation.

Training of selective motor control of the TA muscle in children with CP is a significant component of physiotherapy intervention3 and may help with prevention of plantar flexor contractures. In early childhood, children with CP participate in regular rehabilitation sessions where ankle mobilization, stretching, strengthening, and gait training are used to help encourage selective motor control and decrease spasticity. School age and older children are often provided with a home exercise program and no regular therapy.

Unfortunately, children are often not compliant in following a conventional home exercise program because they find the exercise meaningless and uninteresting. Although there is minimal research regarding the efficacy of a virtual reality training session in children with cerebral palsy for motor rehabilitation,4 studies have demonstrated high levels of interest, fun and motivation with VR.4–6

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In this study, we asked children to complete ankle selective motor control exercises in a conventional (Conv) manner and using a virtual reality (VR) system. We determined whether children with CP were able to appropriately interact with the system and recorded levels of interest and fun expressed by the children and their parents during the VR and Conv exercises. We also recorded the movement kinematics as the children completed the exercises.

METHODS

Participants

Ten children with CP (four male, six female) and six children without CP (two male, four female), 7–17 years old, participated (Table 1). The children with CP included eight children with spastic hemiplegia and two with spastic diplegia. Children with CP had Gross Motor Functional Classification System (GMFCS) scores of 1 or 2, indicating independent ambulation with or without an assistive device.

Equipment

The VR system, Interactive Rehabilitation and Exercise Systems, Ottawa, Ontario, Canada (IREX), consisted of a large television monitor, camera, and computer. The child sat in front of the camera that recorded his or her image. The computer combined the child’s image with an exercise scenario, a game in which the child could keep score. The child saw his or her image as part of the scenario on the large monitor and could interact with virtual objects in the environment.

An electrogoniometer consisting of two metal arms and a parallelogram frame attached to a potentiometer was used to measure ankle joint range of motion. The electrogoniometer was calibrated at intervals of 5 degrees. The output was linear, and the final electrogoniometer records of ankle joint range of motion were converted to degrees using the slope of the calibration curve.

Exercises

Ankle dorsiflexion movements in chair-sitting and long-sitting were completed in both the Conv and VR programs. In chair sitting, the child sat on a stool with the hip, knee, and ankle as close to 90 degrees as possible (Fig. 1A, B). In long sitting, the child sat on the floor with the hip at 90 degrees, knee at 0 degrees, and ankle in a relaxed position (Fig. 1C, D). For both movements, the child was instructed to dorsiflex the ankle to the end of their available range, hold the maximal position for 3 sec, relax, and then repeat. Depending on the degree of spasticity of the lower extremity, children with CP were more or less able to attain the starting position. The range of ankle dorsiflexion motion

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was thus calculated from the initial position for each child.

Two specific applications were created to elicit the ankle movements in the virtual environment: Coconut Shooters and Ninja Flip. Coconut Shooters consisted of a coconut being ejected from the child’s toes. In Ninja Flip, a ninja appeared on the child’s toe, cuing ankle dorsiflexion, and then jumped onto one of four platforms. The degree of ankle dorsiflexion was modified on an individual basis, allowing each child to reach the maximum score. For example, for a child with CP and limited ankle dorsiflexion range, each degree of difficulty may have corresponded to a 2–3-degree movement, while for a child without CP each degree of difficulty may have corresponded to a 5-degree movement.

Protocol

Each participant completed one 90-min exercise session. Ankle dorsiflexion exercises were then completed in 10-min blocks with each block consisting of a set of Conv and a set of VR exercises. An AB-BA design was used with exercise order counterbalanced between children. In each 10-min block, the child completed 2 min of each exercise (chair- or long-sitting), with a 1-min rest period between exercise type (Conv or VR). Children with CP used the most affected lower extremity, whereas children without CP used the preferred leg.

Outcome measures

Following each type of exercise, the child indicated how interesting and how fun the exercise was using a visual analog scale (VAS). Once a child completed a set of VR and a set of Conv exercise, their parent completed similar VASs for their perception of their child’s fun and interest during each exercise type. Comments were also recorded throughout the exercise session.

Post-acquisition processing of the electrogoniometer data provided starting and finishing ankle position for each repetition, time to complete each repetition, repetition hold time, and the number of repetitions completed for each 2-min exercise bout.

RESULTS

Perceptions of exercise programs

All children responded with higher fun and interest (Fig. 2A,B) scores for VR than Conv exercises. All parents indicated their child had more fun and that they would be more likely to do the VR than Conv exercises at home (Fig. 2C,D).

Movement kinematics

On average, significantly more repetitions of the Conv than the VR exercises were completed by the children in both groups ($p < 0.04$, all comparisons). However, participants with and without CP took a significantly longer average time to complete one repetition of a VR exercise compared to the similar Conv exercise ($p < 0.01$, all comparisons). Separate analysis of hold time showed similarly longer average times for the VR versus the Conv exercises (Fig. 3A). When completing VR exercises, the children...
FIG. 2. Scores on visual analog scales (VAS) from children (A,B) and parents (C,D). Note that the lines correspond to the scores of individual children and parents.

FIG. 3. Mean repetition hold time (A) and mean range of motion into dorsiflexion (B).
had to maintain ankle dorsiflexion at the maximal position in order to generate an action, such as the ninja flipping, before starting the next repetition and having a new ninja appear. When completing the Conv exercise, there was no task-oriented incentive other than verbal instruction to hold the extreme position. Most importantly, participants with and without CP recorded consistently albeit not always significantly greater mean ankle active ranges of motion into dorsiflexion during VR versus Conv exercise (Fig. 3B: children without CP, $p < 0.03$, all comparisons; children with CP, $p = 0.09$). With the VR exercises, the children had a goal to attain (i.e., scoring the greatest number of points), whereas with the Conv exercises, children received no feedback on ankle range.

**DISCUSSION**

Even the youngest children were able to complete the tasks within the virtual environment and generate movements necessary to interact with the virtual objects. The children clearly expressed greater interest and fun with the VR exercises commenting that they were “a lot more fun” and “cool.” One child expressed excitement from scoring stating “Whoa, mommy, I got 300. Can I try it with my left foot?” Less effusive comments were recorded with the Conv exercises where children stated “Can I have a nap? I’m tired” and “These are boring.” Parents were equally positive with the VR exercises with statements “She was much more motivated and interested in them as a game,” “much more motivated to try harder and score higher,” “I know the computer exercises would increase his interest and get him involved in doing his stretching on a daily basis.” Similar experiences and demonstrations of enthusiasm have been reported for adults and children using similar technology.

Improvements in selective motor control have been reported in individuals with spastic CP following different intervention paradigms, including technologies such as feedback training, while supplementing regular therapy with an intense period of increased exposure to physiotherapy has been reported to accelerate acquisition of motor skills in some children with CP. The single session with virtual reality clearly resulted in different motor patterns from the children when completing the VR versus the regular exercises. It is unclear whether an intervention trial using VR would result in a change in selective motor control and whether a change would be retained over an extended period.

Importantly, the loss of selective motor control may interfere with overall level of functioning even when other impairments are treated, since the underlying strength and coordination may be limited. There are no specific modalities to treat selective motor control but physical and occupational therapy in conjunction with a home program may improve selective motor control enough to affect functioning. Thus repetitive activities guided by a therapist or as in this case, a virtual environment, and a continuation of repetitive activities in daily functioning may improve gross motor skills.

A main goal in therapy is the transfer of the acquired motor control from the training site to daily living activities. We have previously shown transfer of acquired functional balance and mobility following a VR-based balance intervention with community-living traumatic brain injury survivors as well as healthy older adults (unpublished data). The current data do not allow us to address this question.

**CONCLUSION**

Children generate a greater range of ankle dorsiflexion, demonstrate better control of active ankle dorsiflexion movement, and report greater interest in doing the same exercise when delivered through a VR system than as a stand-alone exercise. Our next series of experiments will characterize the muscle activity generated during the two exercise modes as well as determine retention and transfer of effects following an intervention trial.

**ACKNOWLEDGMENTS**

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**REFERENCES**


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