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Exploring the Feasibility of a Virtual, Home-Based MusicGlove® Protocol for Children with Hemiparetic Cerebral Palsy

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Exploring the Feasibility of a Virtual, Home-Based MusicGlove® Protocol for Children with Hemiparetic Cerebral Palsy

Abstract

Background: The MusicGlove® as an occupational therapy intervention has been shown to improve upper limb function and satisfaction over conventional therapies for adults who have had a stroke, however, its effectiveness with children who have cerebral palsy has not been examined. The purpose of this research was to explore the feasibility of a virtual, home-based MusicGlove® protocol to increase upper extremity function, quality of life, and internal motivation in children with hemiparetic cerebral palsy.

Method: Three participants, ages 6 to 16, diagnosed with hemiparetic cerebral palsy participated in 23 guided sessions using the home-based MusicGlove protocol over 5 weeks. Functional outcomes, quality of life, and intrinsic motivation were measured using the ABILHAND-Kids, Cerebral Palsy Quality of Life, and Intrinsic Motivation Inventory.

Results: Two participants had an increase in percentages of notes hit (13%–20%) following the MusicGlove® intervention. All three participants rated the MusicGlove® as being of value/usefulness and two reported interest/enjoyment in using the MusicGlove®. All three participants and their caregivers reported an increase in quality of life and decrease in perceived difficulty of daily activities.

Conclusion: The virtual, home-based MusicGlove® protocol may be a feasible intervention to improve hand function for children diagnosed with cerebral palsy.

Comments

Disclosure: Flint Rehab donated 4 MusicGlove® devices (3 to research participants, and 1 to researcher Tatiana Kreuzer) to test the device. Devices were used for the study and kept by recipients afterwards. Flint Rehab also allowed the research team access to the beta version of Tenovi for the duration of the study.

Keywords

ABILHAND-KIDS, Intrinsic Motivation Inventory, occupational therapy, quality of life

Cover Page Footnote

We would like to thank Flint Rehab for their gracious donations of MusicGlove® devices for the participants to use in the study. We would also like to thank Chi-Kwan Shea, PhD, OTR/L and Lauren Sheehan, OTD, OTR/L for their support throughout this process.

Credentials Display

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Cerebral palsy (CP) is the most common physical disability in childhood, affecting 1 in 500 children and causing difficulties in muscle control and bilateral function (Hoare et al., 2019; Plasschaert et al., 2019). These difficulties restrict the ability of the child to manipulate objects, which is one of the strongest predictors of limitations in everyday activities (Plasschaert et al., 2019). Since the goal of occupational therapy (OT) is to improve engagement in meaningful everyday activities, interventions that target upper extremity function are often emphasized for those with CP and have been well documented in the literature.

Several systematic reviews commonly cite bimanual training, constraint induced movement therapy (CIMT), virtual reality (VR), and computer-based training as interventions that improve upper extremity function (Hoare et al., 2019; Shierk et al., 2016). These interventions use concepts consistent with the theory of motor learning, which suggests that the acquisition of motor skills is gained through a combination of repetitive massed practice and the experiences gained from the activity (de Oliveira et al., 2016; Friedman et al., 2014; Wille et al., 2009; Zwicker & Harris, 2009). This framework aims to promote the process of neural plasticity, the brain's unique ability to reorganize neural networks, which is the driving force that leads to permanent changes in the capability of movement (de Oliveira et al., 2016; Friedman et al., 2014; Wille et al., 2009; Zwicker & Harris, 2009). Bimanual training and CIMT have been reported to be effective in improving upper limb function (Hoare et al., 2019; Shierk et al., 2016). While there is evidence in support of these motor learning interventions, they are not without some limitations. Many participants have reported difficulties with CIMT because they found the activities to be less meaningful and unexciting (Hoare et al., 2019). In addition, these interventions are typically performed in-person, which may limit the frequency of treatment because of cost and access (Zondervan et al., 2016). Together these limitations prevent many children from engaging in the repetitive massed practice necessary for maximum recovery (Zondervan et al., 2016). While the effectiveness of rehab-based technologies, including VR and computer-based training, are inconclusive because of insufficient high-quality studies, the emerging evidence is encouraging (Hoare et al., 2019; Shierk et al., 2016). Portability, low-cost, intuitive mode of interaction, and engaging content available to users are among the reasons these interventions show promise over conventional options (Olivieri et al., 2013).

The amount of literature on the effects of VR rehabilitation is growing, with recent evidence suggesting that a combination of repetitive massed practice with VR was effective in the improvement of upper limb function in children with movement-related disorders (Bortone et al., 2020; Chen et al., 2015; Olivieri et al., 2013; Wille et al., 2009). Chen et al. (2015) and Golomb et al. (2010) both evaluated the effects of a home-based VR system used by participants for 30 min a day, 5 days a week. The results from these studies revealed functional improvements following VR rehabilitation related to enhanced motor performance in reaching kinematics, grip strength, and finger range of motion. Shin et al. (2016) conducted a 4-week, single-blinded, randomized controlled trial with 46 stroke survivors using a wearable VR device. Data analysis revealed significant improvement in upper extremity motor impairment according to Fugl-Meyer total scores for the wearable VR group both during the intervention and at follow-up (Shin et al., 2016). When compared to conventional practices, VR rehabilitation seems to offer more control for therapists and is customizable to challenge its users.

The controllability and adaptability of VR devices presents a unique motivational source for compliance and carry-over of treatment that is less aggressive and tedious than conventional practices (Chen et al., 2015, 2018; de Oliveira et al., 2016; Golomb et al., 2010; Okmen et al., 2019; Olivieri et al., 2013; Peretti et al., 2017; Weiss et al., 2009, 2014). A systematic review of VR studies with children with CP by Snider et al. (2010) discovered that while evidence of intervention effectiveness conflicted, motivation and volition were improved. Friedman et al. (2014) gathered participant responses to a VR device, the MusicGlove®, which revealed statistically significant levels of satisfaction rated for the VR treatment over isometric exercises and conventional hand therapy. These findings support that VR rehabilitation may provide greater motivation for continued therapy and, thus, garner greater potential for functional outcomes.

The MusicGlove® was specifically developed for both clinic and in-home use and aims to facilitate repetitive practice of functional gripping patterns through an engaging musical game (Friedman et al., 2011, 2014; Zondervan et al., 2016). Use of the MusicGlove® has been shown to promote hundreds of repetitions of functional gripping patterns in just 30 min of gameplay (Friedman et al., 2011, 2014). Pilot studies performed in clinical settings with chronic stroke patients found not only significantly greater improvements in Box and Block Test scores compared to conventional therapy, but also higher motivation and a greater interest in using the device for in-home therapy (Friedman et al., 2011, 2014). Zondervan et al. (2016) evaluated the MusicGlove® as a home-based intervention compared to home-based conventional therapy in a randomized, controlled single-blinded study. Although there were no significant differences in outcome measures between groups, there was a significant increase in self-reported improvements of functional hand use and quality of movements when using the MusicGlove® as measured by the Motor Activity Log subscales *Quality of Movement* and *Amount of Use* (Zondervan et al., 2016).

The recent COVID-19 pandemic has challenged the way health care services are being delivered. With social distancing becoming essential to reducing the spread of the virus, many health care services have shifted to a telehealth delivery model (CDC, 2020). Combining telehealth with rehab-based technologies poses a useful way for therapists to provide supervision for therapeutic success without placing the burden on families to visit a clinic (AOTA, 2018; Peretti et al., 2017). A systematic review by Peretti et al. (2017) reviewed articles published from 1996 to 2016 and found that telehealth using gaming techniques garnered promising results in therapy gains. Increased quality of life and decreased depression were reported in people who received interventions that were delivered remotely (Linder et al., 2015). This suggests that telerehabilitation offered in-home is a valuable approach to providing therapy services when access to in-person care is limited. Since telehealth has become a way of providing services during the pandemic and is expected to expand beyond the pre-COVID-19 era, more research is warranted to expand the knowledge in these emerging areas of practice (Ben-Pazi et al., 2020).

In-person repetitive mass practice of functional movements has been effective for regaining motor control and facilitating improvements in upper limb function. However, restrictions related to in-person treatment and motivation have impacted the efficiency of most motor learning interventions. This study will be the first to look at the use of the MusicGlove® with the CP population. Given the transition to telehealth because of the COVID-19 pandemic, a home-based MusicGlove® protocol was developed using motor learning principles as a therapeutic guide for this population. The purpose of this study is to determine the feasibility of a virtual, home-based MusicGlove® protocol to answer the following question: Does this home-based MusicGlove® protocol increase (a) internal motivation? (b) upper extremity use in functional tasks? and (c) perception of quality of life?

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Method

Study Design

This study was approved by the Samuel Merritt University Institutional Review Board. This exploratory study was designed as a case series in which all participants were enrolled in the intervention and acted as their own control to explore the feasibility and efficacy of a home-based protocol delivered remotely through a telehealth platform. Twenty-three, 60-min guided sessions, including an orientation, a pretest, a posttest, and 20 treatment sessions following the home-based MusicGlove® protocol, took place over 5 weeks. The purpose was to see if using the MusicGlove® with a home-based protocol improved upper extremity hand function in children and adolescents with hemiparetic CP. Data on manual abilities, quality of life, and subjective experiences related to the MusicGlove® and the home-based protocol were collected pre and post intervention to measure efficacy and feasibility.

Participants

Participants were selected through convenience sampling techniques through word of mouth and fliers posted on family support groups through social media. Interested families contacted the researchers through email to determine eligibility. Potential candidates were identified following a meeting with the researchers to determine eligibility by completing a prescreen form, which included confirming a diagnosis of hemiparetic CP.

Participant inclusion criteria were as follows: The participant must have a diagnosis of hemiparetic CP, be between 6–17 years of age, be able to oppose at least one finger to thumb, and be categorized as Level I or II on the Manual Abilities Classification System (MACS) and the Communication Function Classification System (CFCS). MACS Level I and II are classified as “handles objects easily and successfully” and “handles most objects but with somewhat reduced quality and/or speed of achievement” (Eliasson et al., 2010, p. 2). CFCS Level I and II are classified “effective sender and receiver with unfamiliar and familiar partners” and “effective but slower paced sender and/or receiver with unfamiliar and/or familiar partners” (Communication Function Classification Systems, n.d., p. 3). Because this study involved telehealth and video gaming, the participants were required to have a computer capable of running the MusicGlove® software, an internet connection of at least 1 Mbps upload/download speed, a webcam or video conferencing device, a valid email address for communicating with the researchers throughout the study, and a caregiver available to assist as needed during each session.

Children or adolescents were excluded from the study if they had an allergy to nickel, could not attend to a video game for at least 15 min, did not have a hand size that could fit into the gaming glove, had an injury to their affected hand that would inhibit them from being able to safely don the gaming glove, or could not speak or read English. To isolate the effects of the intervention, potential participants were excluded if they were currently receiving OT for their upper extremity, scheduled to have a change in oral spasticity medication during the study, or scheduled to receive surgery or botulinum toxin injections to the affected upper extremity within the study time frame.

Three participants met inclusion criteria and were enrolled in the study. All three participants had a diagnosis of hemiparetic CP, and one participant also had a diagnosis of ADHD, which was revealed mid study. Participant 1 had hypertonicity that affected the participant’s ability to supinate and maintain the forearm in a neutral position independently to complete the grips. Therefore, the caregiver was initially assisting the participant to supinate the forearm to maintain a neutral position while engaging in the MusicGlove® game as it was intended. See Table 1 for further description of the participants' characteristics. All parents provided informed consent and all children provided assent.

Table 1
Participant Characteristics

Participant	Age	Affected extremity	Tone	Functional status	Adherence to home program	Modifications to protocol
1	16	Right	Hypertonia	MACS Level II CFCS Level I	Yes (11/11 independent home sessions completed; 12/12 virtual visits with researcher present completed)	Game play was limited to songs with 65 or less grips for middle and index fingers because of tone and endurance Progressed to multiple grips once able to demonstrate the ability to complete the single grip with modified independence
2	13	Right	Fluctuating tone	MACS Level I CFCS Level I	Yes (10/10 independent home sessions; 13/13 virtual visits with researcher present)	Ring grip was eliminated from gameplay during the last session because of a malfunction, as those sensors did not register contact and the participant verbalized feeling "frustrated"
3	6	Left	Hypotonia	MACS Level II CFCS Level II	Yes (11/12 independent home sessions; 10/11 virtual visits with researcher present)[a]	No modifications were made

Note. None of the participants were taking oral spasticity medication.
[a]Intervention ended two days early because of a family emergency.

Instruments

MusicGlove® and Tenovi

This research was conducted using the commercially available MusicGlove® device and Tenovi, a remote performance monitoring platform, which were both provided by Flint Rehab, the manufacturer of the MusicGlove®. The MusicGlove® is a music-based rehabilitation device designed to facilitate repetitive practice of functional gripping patterns through an interactive gaming system (Friedman et al., 2011, 2014; Zondervan et al., 2016). The game consists of five musical notes that correspond to the key pinch and thumb opposition gripping patterns (Friedman et al., 2011, 2014; Zondervan et al., 2016). The user is provided visual cues for timing and execution of grips as color-coded notes scroll down the screen along distinct frets. Sensors, located on the fingertips of each digit and the lateral aspect of the index finger, track the user's hand performance. The goal is to accurately complete as many notes as possible per song. The quantitative assessment of hand performance includes the total number of correct notes, the number of correct notes per grip, and the accuracy of the user's timing and performance presented as an average of how close to the desired time the grip was executed (Friedman et al., 2011, 2014).

Tenovi is the remote monitoring software developed by Flint Rehab. This software was connected to the MusicGlove® gaming software installed onto each participant's computer. Each time the participants opened the MusicGlove® game a file was generated with gameplay statistics and uploaded to the Tenovi application. The researchers were able to access this data through the application to monitor participant compliance and progress in their home-based protocol. Information displayed on Tenovi included level of difficulty attempted, finger grips, notes hit, percentage of notes hit, and time played.

ABILHAND-Kids

ABILHAND-Kids is a criterion-referenced, parent-report questionnaire rating the perceived difficulty of daily activities in children and adolescents with CP. It consists of 21 items and asks parents to rate each item as easy, difficult, or impossible. This measure was chosen for its high reliability ($R = 0.94$) and reproducibility ($R = 0.91$) (Arnould et al., 2004). The ABILHAND-Kids was administered to parents both pre and post intervention.

Cerebral Palsy Quality of Life

The Cerebral Palsy Quality of Life (CP QOL) is used to evaluate quality of life of children with CP. This questionnaire is based on the International Classification of Functioning, Disability and Health (Waters et al., 2007). The CP QOL-Child form is used for children ages 4 to 12 years and consists of two versions: a parent-proxy version that has 65 items, and a child self-report version that has 53 items. The child self-report version is only used for children ages 9 to 12 years. The CP QOL-Child includes the following domains: social wellbeing and acceptance, feelings about functioning, participation and physical health, emotional wellbeing and self-esteem, access to services, pain and impact of disability, and family health. The CP QOL-Teen form is used for adolescents 13 to 18 years of age and it consists of two versions: an adolescent self-report version that has 72 items, and a parent-proxy version that has 88 items. The CP QOL-Teen includes the following domains: general wellbeing and participation, feelings about functioning, communication and physical health, school wellbeing, access to services, social wellbeing, and family health. The CP QOL uses a 9-point Likert scale where 1 is *very unhappy* and 9 is *very happy*. For this study, overall wellbeing and feelings about functioning domains were used.

Both the CP QOL-Child self and parent report have been found to have good reliability (internal consistency ranged from 0.74–0.92) (Waters et al., 2007). Both the CP QOL-Child self- and parent report also have been found to have good construct validity. Both forms were shown to have moderate correlation with global quality of life ($r = 0.18$–0.64) and global health ($r = 0.21$–0.60) (Waters et al., 2007). Both the CP QOL-Teen self- and parent reports also were found to have good reliability (Cronbach's alpha ranges from 0.78–0.96) (Davis et al., 2013). Both the CP QOL-Teen self and parent reports also were found to have adequate construct validity showing moderate correlations between generic and condition specific measures of quality of life and between both reports (Davis et al., 2013).

The participants and parents were administered their corresponding CP QOL questionnaires both pre and post intervention.

Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI) was selected to reflect the child's subjective experience using the MusicGlove® game to capture satisfaction measures and likelihood to continue using the intervention. The IMI uses a 7-point Likert scale where 1 is *not true at all* and 7 is *very true*. This assessment was chosen for its strong validity in assessing internal motivation factors and internal consistency reliability with Cronbach's alpha of 0.85 (McAuley et al., 1987). A 25-question version on activity perception was administered to the participants post intervention. Subscales of interest and enjoyment and value and usefulness were collected.

Procedure

The home-based MusicGlove® protocol was developed using motor learning principles to help guide the user through a systematic progression of motor skill acquisition and retention. The MusicGlove® program involves five gripping patterns and includes three levels of difficulty (easy, medium, and difficult) consisting of songs with increasing demand for speed and dexterity. The program allows the user to select specific gripping patterns and the level of difficulty per gaming session. The home-based MusicGlove® protocol provides an outline for treatment progression and includes six phases, beginning with three single grips and progressing to the incorporation of all five gripping patterns.

In the first session, the ABILHAND-Kids was administered and the participants were asked to choose three of the 21-items as their goal focus for the treatment sessions. The corresponding finger grips related to the participants' goal items were used to create the treatment plan for each session. The CP QOL questionnaires were also completed by the participants and parents. The second session occurred 1–2 days after receiving the device in the mail as a guided orientation. During this session, the participants were instructed to "think aloud" their thoughts and feelings while they set-up and played one practice game with the MusicGlove®. The Think Aloud process was included to gather subjective experiences on how a participant views their play-based experience and how they made sense of the user interface of the MusicGlove® device and software (Lewis & Rieman, 1993). The remainder of the orientation session included an introduction to the welcome packet PDF, which included a telehealth troubleshooting guide, environment setup guide, MusicGlove® user guide, hand stretches, score recording log, and handwashing protocol, followed by the completion of one MusicGlove® gaming session to gather baseline performance measures. Baseline performances used a single finger grip, which was identified as the primary goal grip through the ABILHAND-Kids report.

Treatment sessions were 60-min each and were performed five times a week over 4 weeks for 20 sessions. During each week, at least two treatment sessions were conducted via video visits with the researchers present and the remaining sessions were performed independently by the participants with caregiver oversight. The purpose of the bi-weekly virtual visits with the researcher was to help individualize and progress the participants through the home-based MusicGlove® protocol.

The participants received an email from the researchers each morning containing instructions on which grip(s) to select in the MusicGlove® game and how to record their scores on the log sheet. Each treatment session was divided into three 15-min gaming sessions. Between each 15-min session, the participants would perform the hand stretches provided in the welcome packet for 5 min. Treatment sessions conducted with researchers continued to employ the Think Aloud protocol to tailor and optimize the session to the participants' needs. This process was useful to make suggestions in screen and device positioning, as well as proper body positioning and support devices to stabilize posture when necessary.

Data Analysis

Because of a small sample size of three, descriptive statistics of the scores from each instrument combined with qualitative data collected during the sessions were analyzed.

Results

Table 2 shows that two out of three participants had an increase in percentages of notes hit following the MusicGlove® intervention of 13.18% and 20.85%. Participant 2 had a decrease in percentage of notes hit following the MusicGlove® intervention by 1%. However, it is noted that during the posttest, Participant 2 demonstrated the ability to do a key grip but the sensors for the key grip were not registering.

Participant 3 received a new glove for the posttest because the sensors were malfunctioning on the original glove. The new glove was smaller for a better fit. Three songs were played during the posttest. Participant 3 wore the new glove, a size extra small, for the first song but demonstrated difficulty aligning the key grip on the new glove, as 44/64 (68%) notes were hit. For the next two songs, Participant 3 wore the original glove, a size small, and performance improved as 56/65 (86%) and 103/103 (100%) were hit, respectively.

Table 2

MusicGlove® Baseline and Post Intervention Performance

Participant		Selected grip	Level of difficulty	Positioning	Score
1	Baseline	Key	Easy	Benik wrist cock up splint was tried for the 3rd song but it made gameplay more difficult, so it was removed for the 4th song. Instead, the caregiver provided maximum wrist and forearm support to maintain a neutral position and stabilize the thumb carpometacarpal joint to facilitate key pinch.	66.46%
	Post	Key	Easy	Chest and leg harnesses attached to the wheelchair were used to provide trunk stability. Caregiver provided minimal forearm and wrist stabilization to maintain neutral position.	87.31% (+20.85%)
2	Baseline	Key	Easy	N/A	94.25%
	Post	Key	Easy	N/A	93.25% (-1%) [a]
3	Baseline	Key	Easy	N/A	75.13%
	Post	Key	Easy	N/A	88.31% (+13.18%)[b]

Note. Changes in score are in parentheses.
[a]Key grip was not registering during the posttest.
[b]A new extra small size glove was worn for the first song, then the original small size glove was worn for the remaining two songs.

As seen in Table 3, the results of the IMI showed a favorable response to the MusicGlove® home-based protocol on both subscales. All three participants rated the value and usefulness of their MusicGlove® experience as a 5 or higher (5, 5.56, 6.56). Interest/enjoyment scores had a wider range of 4 (*somewhat true*) to 6 (*very true*) (4.06, 5.38, 6). The lowest score for interest/enjoyment was recorded by Participant 2, who remarked on several occasions about the limited music selections.

Table 3

Intrinsic Motivation Inventory (IMI) Scores Post Intervention

Participant	Subscales	Score	Responses
1	Interest/ enjoyment	5.38	• The mother and participant intermittently sang along with the songs in the first session. • Here are some of the responses that the participant reported as true: ○ This activity was fun to do. ○ I enjoyed doing this activity very much. ○ I thought this was a very interesting activity.
	Value/ usefulness	5.56	• The mother and participant shared improvements with the physicians. • Here are some of the responses that the participant reported as true: ○ I am willing to do this activity again because I think it is somewhat useful. ○ I believe doing this activity could be somewhat beneficial for me. ○ I would be willing to do this activity again because it has some value for me.
2	Interest/ enjoyment	4.06	• Preferred other songs that were not part of gameplay: Participant reported to be "more motivated" when listening to Hamilton in the background and that "Black Sabbath would be better songs to listen to." • Different song rotation: "Once you know all the songs it is ugg." • Glove malfunction: "frustrated, annoyed, and bummed." • Here is a response that the participant reported as somewhat true and true: ○ I thought this was a boring activity. ○ This activity was fun to do. ○ I enjoyed doing this activity very much.
	Value/ usefulness	5	• The participant reported that she "will probably continue to use the glove" and "I think I will keep playing it, but only a few times a week." • Here are some of the responses that the participant reported as true: ○ I believe that doing this activity is useful for improving concentration. ○ I believe that doing this activity could be somewhat beneficial for me.
3	Interest/ enjoyment	6	• During the administration of the IMI, the participant reported "wanting all happy faces" and "feeling really happy today." • Observed to be more engaged and have better performance during favorite songs: ○ "I like this song" and sang along to songs. ○ Reported to prefer "faster" more upbeat songs. • Here are some of the responses that the participant reported as very true: ○ I felt like I was enjoying the game while playing it. ○ I would call this game very enjoyable. ○ I would call this game very fun.
	Value/ usefulness	6.56	• Here are some of the responses that the participant reported as very true: ○ I think playing the game helped me pay more attention. ○ I am willing to play this game again because I think it was very helpful. ○ I think that playing this game was very helpful for me.

Note. The participants answered questions from the IMI on a 7-point Likert scale and each subscale score was an average of the scores from the responses.

As seen in Table 4, quality of life for feelings of function increased across all reports from the participants and their caregivers (+15, +15, +5, +2.5, +22.72). Two out of three participants and all caregivers reported increased overall wellbeing and participation (+5.35, +2.97, +16.67, +12.48). Participant 2 was the only participant who had a decrease in overall wellbeing scores (-0.58).

Table 4
CP QOL Baseline and Post Intervention Scores

Participant	Form	Pre/Post	General Wellbeing and Participation	Feelings About Function	Responses
1	Child	Pre	80.36	62.5	• Caregiver and Participant 1 reported increased forearm supination resulting in almost full range of motion, decreased pain, and increased strength. • Examples of responses with positive changes that both the caregiver and participant reported: ○ Hanging out with friends. ○ Participating in leisure/recreation activities. ○ Ability to participate in sports.
		Post	85.71 (+5.35)	77.5 (+15)	
	Caregiver	Pre	57.74	40	
		Post	60.71 (+2.97)	45 (+5)	
2	Child	Pre	64.29	67.5	• "Ya, but not as good as I want them [MusicGlove® scores] to be." • "Difficult not being able to see friends during shelter in place." • Examples of responses with negative changes that the participant reported: ○ Ability to get around your neighborhood. • Examples of responses with positive changes that both the caregiver and participant reported: ○ Ability to dress yourself. • Examples of responses with significant positive changes that the caregiver reported: ○ Being able to do the things they want to do. ○ The way they get around.
		Post	63.69 (-0.58)	82.5 (+15)	
	Caregiver	Pre	54.76	60	
		Post	71.43 (+16.67)	62.5 (+2.5)	
3	Caregiver	Pre	59.38	38.64	• Examples of responses with positive changes that the caregiver reported: ○ Ability to dress themselves. ○ Ability to drink independently. ○ Ability to use the toilet by themselves. ○ Ability to play with friends.
		Post	71.86 (+12.48)	61.36 (+22.72)	

Note. Participant 3 did not complete a self-report form because of age outside of age criteria.

For the ABILHAND-Kids, the caregivers, with input from the participants, rated daily activities as easy, difficult, or impossible. Easy was given a score of 2, difficult was given a score of 1, and impossible was given a score of 0. Table 5 shows that all three caregivers and participants reported a decrease in perceived difficulty of daily activities post intervention as shown by an increase in scores (+6%, +15%, +25%).

Table 5

ABILHAND-Kids Baseline and Post Intervention Scores

	Score		Patient Measure (logits)		Standard Error (logits)	
Participant	**Baseline**	**Post Intervention**	**Baseline**	**Post Intervention**	**Baseline**	**Post Intervention**
1	18	22	-0.50 (47%)	0.17 (53%)	0.41 (3%)	0.41 (3%)
2	32	40	2.39 (68%)	4.38 (83%)	0.49 (4%)	0.76 (6%)
3	24	39	0.51 (54%)	3.90 (79%)	0.41 (3%)	0.66 (5%)

Table 6 shows the three ABILHAND-Kids goal items that each participant, with feedback from their caregiver, selected at the initiation of the intervention and their rating of perceived difficulty on their goals pre and post intervention. Each of these activities have a component that requires use of a key grip or thumb opposition to complete the activity successfully. Participant 1 showed no change in perceived difficulty with goals, rating that all three activities were difficult pre and post intervention. However, the parent and participant both reported that although those activities continue to be difficult for the participant, the participant did have increased participation and independence with activities related to the goals. In addition, Participant 1 has hypertonicity affecting supination range of motion at baseline, which was noted to improve by the participant and caregiver in preparation for these goal activities, such as supinating the forearm to a neutral position to stabilize the glass of water when filling it up. Participant 2 reported the greatest change in perceived difficulty with goals from difficult to easy. However, the parent reported opening a bag of chips continues to be difficult although the participant reported it to be easy. Participant 3 reported less difficulty in two out of three goals, while the goal of zipping up a jacket remains difficult.

Table 6

Perceived Difficulty on Participant Selected Goals from ABILHAND-Kids

Participant	Goals	Pretest	Posttest	Responses
1	Primary: Unwrapping a chocolate bar	Difficult	Difficult	• Mother and participant reported increased participation in family cooking activities throughout intervention. • Mother shared a video of the participant unwrapping a chocolate bar independently with extra time to complete. • The participant shared she had greater participation in a baking project and was able to open all toffee bar wrappers. • The participant reported, “I def built stamina. I think my finger is getting used to it.” • Mother reported almost full range of supination by end of intervention whereas at baseline, the participant had decreased range. • Mother reported, “I’m providing less [wrist and forearm] support [in game play].”
	Taking off a T-shirt	Difficult	Difficult	
	Filling a glass with water	Difficult	Difficult	

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Participant	Goals	Pretest	Posttest	Responses
2	Primary: Zipping-up trousers	Difficult	Easy	• Caregiver reported improvements in grasping, turning doorknobs, and manipulating Legos. Caregiver reported that the participant is "able to open Ziplock bags and turn key in locks better."
	Buttoning up trousers	Difficult	Easy	
	Opening a bag of chips	Difficult	Easy (child) Difficult (parent)	
3	Primary: Buttoning up trousers	Impossible	Difficult	• Caregiver reported the participant has improvements in opening packaging (i.e., bars and snack bags). • Caregiver reported that the participant can button a shirt/sweater with a little extra time. • Caregiver reported that the participant can open a bag of chips with verbal cueing of "tear it like paper."
	Fastening snap of jacket	Impossible	Easy	
	Zipping-up jacket	Difficult	Difficult	

Discussion

A home-based MusicGlove® protocol was developed using motor learning principles to help guide the user through a systematic progression of motor skill acquisition and retention. The three participants enrolled in this study varied in age, functional abilities, and level of independence. This provided valuable information for special considerations and potential modifications to the home-based MusicGlove® protocol, as well as general impressions of device use with the pediatric and CP populations. This study was designed to answer the following questions: Does this home-based MusicGlove® protocol increase (a) internal motivation? (b) upper extremity use in functional tasks? and (c) perception of quality of life?

Modifications to the home-based MusicGlove® protocol were made for both Participant 1 and 3, based on the researcher's clinical reasoning. The progression through the protocol was adjusted by the researcher to accommodate for Participant 1's hypertonia and spasticity to ensure the quality of the movement was mastered prior to moving onto the next level. External supports for positioning, including physical assistance from mother and positional devices, were used throughout the intervention. Songs were also limited to those with fewer grips (65 and under) as songs with more grips would increase spasticity and fatigue. Therefore, Participant 1 remained on the easy level of gameplay and repeated songs with fewer grips. Because of hypertonia, Participant 1 also had difficulty shifting from one grip to another as noted through participant feedback and effort observed. Therefore, the goal was to perform single grips with improved quality and modified independence before combining grips. During the last two sessions, Participant 1 progressed to combining two grips, the middle and index fingers, for which the thumb spica cast was used. Despite the delay in combining grips, Participant 1 and caregiver provided subjective reports of increased range of motion and stamina while demonstrating increased execution of grips throughout the intervention.

Because of inconsistencies in performance scores for treatment sessions completed individually versus with the researcher present, progression of the home-based MusicGlove® protocol took place during Participant 3's virtual visits only. The participant's younger age, attention deficit hyperactivity disorder (ADHD) diagnosis, and incentive to please the researchers may have been contributing factors to these inconsistencies in performance scores. Participant 3's family was also reminded throughout the intervention to follow the environmental setup guide to decrease distractions.

Given the various modifications to the home-based MusicGlove® protocol, participant positioning, and environmental setup, a skilled occupational therapist is recommended for the implementation and oversight of the protocol to meet the participant's individual needs. Based on the client's individual needs, the occupational therapist can use their clinical reasoning on frequency and duration in terms of providing direct services or consultation.

Previous studies have shown the benefits of the MusicGlove® as an intervention for people who have experienced a stroke in terms of functional hand use, quality of movements, and motivation, and found that there were improved performances on the MusicGlove® following intervention (Friedman et al., 2014; Zondervan et al., 2016). This is the first study using the MusicGlove® as an intervention for children with CP. All three caregivers and participants reported a decrease in perceived difficulty of daily activities and improved hand function post intervention. Hand function requires thumb opposition and several fundamental movement patterns of the fingers and thumb, in which the MusicGlove® targets these patterns (Zondervan et al., 2016).

Two out of three participants demonstrated an increase in scores on the MusicGlove® performance after intervention. Participant 2 showed a minor decrease in score (-1%) from pretest to posttest. During the posttest, Participant 2 demonstrated the ability to do a key grip but the sensors for the key grip were not registering. Therefore, the actual performance may have been higher than the recorded score.

Participant 3 completed three songs during the posttest. Participant 3 received a new glove for the posttest because the sensors were malfunctioning on the original glove. A different size was ordered for a better fit based on the measurements. The original glove is a size small, and the new glove is a size extra small. Participant 3 wore the new glove for the first song and had difficulty aligning the key grip on the new glove, as 44/64 (68%) notes were hit. For the next two songs, Participant 3 wore the old glove, which is a size small, and performance improved as 56/65 (86%) and 103/103 (100%) notes were hit. Therefore, Participant 3's score may have been higher if he had used his original glove for all three songs of the posttest.

To determine the glove size, the manufacturer provided a sizing guide displaying an outlined image of the index finger, with minimum and maximum millimeter width and a representation of coins where smaller than a dime is an extra small glove, a dime is a small glove, a nickel is a medium glove, and a quarter is a large glove. This two-dimensional guide did not account for circumferential measurements of the hand. Other issues contributing to glove fit challenges included the lack of stretch in finger cot material and limited adjustability on finger lead lengths. Two participants had issues with the lack of stretch in the thumb cot opening. The hyperextension in Participant 1's thumb interphalangeal joint because of hypertonicity did not allow for the cot to be fully donned and it would periodically pop off. Participant 2 felt a tightness around the area and used small toys to stretch out the cot, which resolved the fit issue. For Participant 3, despite measuring as a size small on the sizing guide, the lack of adjustability in the finger leads led to the sensor for the key grip not aligning. Tape was used to secure the leads and sensors in the proper position. A material or design that can accommodate greater adaptability to ensure a proper fit while considering the variability of both hand shape and size may be better suited for the pediatric population and those with hypertonicity.

Preliminary findings support that the MusicGlove® intervention increased feelings about functioning and quality of life. All three participants reported a decrease in perceived difficulty of daily activities and increase in feelings of function as it pertains to quality of life. This is consistent with previous studies reporting functional improvements related to performance skills such as reaching, grip strength, and finger range of motion following VR therapy (Chen et al., 2015; Golomb et al., 2010). Specifically, with the MusicGlove®, Zondervan et al. (2016) found a significant increase in self-reported improvements of functional hand use and quality of movements with this intervention. Throughout the study, all three participants and their caregivers reported and shared videos of the participants' progress with the researchers in terms of their participation and independence in daily activities, such as opening food wrappers and manipulating fasteners.

Last, all three participants found the home-based MusicGlove® protocol to be intrinsically motivating, as the participants reported the intervention to be fun, enjoyable, motivating, beneficial, and helpful. This is consistent with a previous study that found the MusicGlove® to be more motivating than conventional therapy interventions (Friedman et al., 2014). Therefore, preliminary data shows that the MusicGlove® could be an effective intervention toward functional improvements as an adjunct to OT.

Limitations

Limitations of this study include small sample size, short intervention period, non-randomized design and lack of control group comparison, limited selection of assessments because of remote administration restrictions, and various unpredictable technical issues related to the MusicGlove® software and beta version of the remote patient monitoring system, Tenovi. While the ABILHAND-Kids is a quick and easy to administer questionnaire, the broad categories of easy, difficult, and impossible lack the sensitivity of change related to the MusicGlove® intervention. In addition, measurements such as range of motion and grip strength, would have been beneficial if in-person assessment was permitted.

OT Implications

Currently, there are limited published studies investigating the MusicGlove® device, for which participants had previously experienced a stroke. This research study examining children and adolescents with CP, not only contributes to the MusicGlove® research, but also expands on the age range and diagnoses investigated. Researching this new population will help inform clinicians about the usability of this rehabilitation device for both the pediatric population and those diagnosed with CP. In addition, the home-based MusicGlove® protocol presents a systematic progression through the MusicGlove® program that can be used by clinicians and patients to help improve fine motor skills and promote functional gripping patterns. This protocol can be used as an intervention strategy to facilitate motor skill acquisition and retention to help users achieve goals related to hand function. In order to maximize therapeutic benefit and minimize the risk of misuse or development of atypical gripping patterns, a therapist should be consulted to help progress the client through the protocol to best meet the client's individual needs.

This study also showed the feasibility of telehealth as a service delivery model for OT interventions, as telehealth allowed potential clients and families to access the MusicGlove® intervention without the burden to visit a clinic. The protocol could also be customizable and monitored by an occupational therapist to fit each individual participant's needs in their natural environment. The remote administration of this research study shows that in-home use of the device following the home-based MusicGlove® protocol is feasible.

Future Research

Future studies involving a larger sample size and randomized control trial design is recommended. Expansion of the intervention period and the addition of a follow-up assessment would be beneficial to evaluate the retention of motor skills. Incorporating motion analysis to evaluate quality of movement would provide valuable information on the outcomes of this intervention in relation to the researchers' clinical observations.

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