Balance and Muscle Memory in Physical Therapy for Children with Cerebral Palsy

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Engineering 81
11 December 2019

Abstract

Cerebral Palsy (CP) is the general term for a collection of muscle disorders that are caused by a number of complications that result in brain injury such as trauma or genetic mutation. CP manifests itself in patients as either weakness, stiffness, or jerkiness in anywhere from the upper extremities to the lower extremities and it occurs physiologically in part as a result from improper length of contractile units called sarcomeres in the muscle cell. There are 4 types of CP: Spastic CP, Athetoid CP or Dyskinetic CP, Ataxic CP, and Mixed CP. There are many treatment options available for those with Cerebral Palsy, whether for motor development or pain alleviation but there is currently no cure. There are a myriad of devices and contraptions currently in use to help individuals with CP improve muscle function, strength and balance. This paper focuses on a new device designed to help improve balance coordination, as well as developing muscle strength and movement for those with CP. The goal of our versatile device is to allow a patient to regain balance coordination, proper posture, and provide strength training while enjoying what they are doing with an interactive component.

Introduction and Specific Aims

Cerebral Palsy (CP) is a group of disorders that debilitates most of a person's motor functions. It is caused by abnormal brain development, which does not allow for control over muscle movements. CP causes difficulty in maintaining the balance of limbs and posture. Many individuals with this disorder require other means of assistance to help them get around such as using a walker or wheelchair. People who suffer from CP are required to undergo physical therapy training in order to rehabilitate and develop strength in their muscles. Physical therapy also allows the development of balance, posture maintenance, and ability to regain motor function. (Mayo Clinic).

The goal of our design is to help children with cerebral palsy regain balance and coordination by providing assistance while they use the device, and making those parts detachable. Our design is focused on lower limb movement, which heavily relies on the ability to balance. This will consequently require that the patient build up their balancing abilities while using our device, which will further allow them to walk. Without proper balance, it is almost impossible for the patient to perform any lower limb motor functions. The hope is that it will work through developing muscle memory, and as a result strengthen neural connections in the muscles. To help develop balance, the device can be used while the individual is either sitting or standing. If it is difficult at first for the patient to stand up, they may use the device while sitting down. Once they feel more comfortable, there will be arm supports as well as back and upper torso support to keep them in the correct position while using the device. When the patient is able to support their own body weight, the back and arm supports can be removed.

Patients who will initially be using this device will be of younger age, therefore it is important that the device be interactive and fun for these patients to use. Since intensive training requires a commitment of 4-6 hours per day, the child might lose interest in wanting to continue their treatment during this extended period of time. Our device will allow the patient to complete their treatment in a comfortable setting while doing other tasks they may enjoy, such as watching TV, playing games, or interacting with others. This device will also include an optional video game component that will allow the user to complete their mandated exercises but have a task they must complete through the video game simulation, such as moving their foot in order to virtually kick a ball. Since it may be difficult for some to be able to go to a physical therapy center, another goal with this device is to bring the physical therapy to them, and at a lower cost (since this is something that is able to be purchased for use in the home).

This device will also allow the patient to begin to develop strength in weak leg muscles though various leg movements and exercises. Studies have shown that physical therapy has proven effective for assisting children in regaining their range of motion (Damiano, 2006). By continuously targeting the same muscles in similar movements, the peripheral nervous system neurons innervating the muscles and their associated central nervous system neurons will eventually ‘remember’ the movement and make it easier for the patient to conduct these movements independently. The way these muscles “remember” these movement is through subsequently stronger neuro-chemical effects such as ‘firing’ from neurons (Carmeli, 2016). What we refer to as muscle memory is actually the same memory as that in the brain: it involves the same electrical and chemical connections of neurons except these connections synapse onto muscles, making what are known as motor units, or singular neurons and all of the muscle cells that they innervate. Muscle development therefore has both a muscular and neuronal component but the growth of the myofibrils and muscle cells is of course an important. Muscles are made up of what are known as motor units, or singular neurons and all of the muscle cells that they innervate. Muscle development therefore has both a muscular and neuronal component but the growth of the myofibrils and muscle cells is of course an important aspect. By developing muscle strength, there is also an inherited development of muscle coordination and coordination of movement.

Our device also aims to create versatility. The device will be used for children with different types of cerebral palsy, different sizes (height, weight) and different skill levels. Coordination of balance and leg movement is a common disability factor among all types of cerebral palsy. The armbands (attached to the arm supports) limit the spastic motions that come with certain types of CP. The back supports and arm supports are adjustable based on height and arm length of the child. The foot pads have velcro straps to keep feet of all sizes in place when the device moves the child’s foot in certain directions. The strap on the foot pad also helps the child keep their position and stay on track when they attempt to move their feet on their own. The device adapts to a child’s increasing skill level via sensors and can adapt to the child’s needs (in terms of skill or physical support). At the beginning, when the child needs more support, the device will do most of the work in moving their feet and legs for them. As the child gains practice and makes visible progress, the machine will not have complete control and will allow the child to move the foot pads using their own force and strength. Of course, the machine will continue to assist, but provide less help in order to allow the child to develop the required strength on their own, and will revert back to providing maximal assistance if there is a regression in the patient's progress for some reason. The materials that the device is made of are able to support large amounts of weight (about 200lbs). This weight is an overestimation since children with CP are typically underweight.

Background

Cerebral Palsy (CP) is defined as a congenital disease that affects a person's muscle tone and posture as well as causes restricted movement. It is categorized as a brain disorder and is due to many risk factors, such as various birth complications, multiple births, genetic mutation, and traumatic brain injury. According to the CDC, Cerebral Palsy affects about 1 in 323 children. CP generally demonstrates very stiff ("high") or very floppy muscle tone, which may delay certain motor skills. In comparison to children without CP, muscle fiber length has been found to be significantly shorter, as well as having decreased muscle volume (Barrett & Lichtwark, 2010). About 41% of children with CP have limited ability in walking and crawling, and about 31% require the support of an external device, such as walkers or a wheelchair to allow them to be mobile (CDC). Those with CP also have difficulty with fine motor movements as well. CP is often coupled with autism spectrum disorders and epilepsy, generally among those with CP and no walking ability (Christensen et al., 2014).

The musculoskeletal system is one of the best examples of functioning complexity in the human body: muscles that attach to bones and are innervated by nerves to produce every voluntary bodily movement. There are three types of muscle: smooth, cardiac, and skeletal. Smooth and cardiac muscles are involuntarily controlled and by our autonomic nervous system while skeletal muscle is under voluntary control courtesy of our somatic nervous system. Cardiac muscle is that of the heart's contractile tissue paramount to generating and executing the force to move blood around the body. All other muscle tissue in the body is either smooth (e.g. muscle in the stomach, eyes, and small and large intestines) or skeletal (e.g. muscles such as our biceps, triceps, and quadriceps). Both the muscular and skeletal systems are made up of many individual components each that are able to work in unison to produce fine and gross motor movements. During development, symmetry and appropriate length and proportion of the muscles and skeleton are crucial to proper muscle growth even from embryogenesis (De Rezende Pinto et al., 2015). Despite the staggering complexity, the musculoskeletal system is consequently vulnerable to myriad structural issues and therefore functional issues (McLeod et al., 2016), including cerebral palsy.

In CP, muscle development is interrupted from the microscopic contractile units of muscle up to certain gross systemic aspects and it takes on distinct anatomy and pathophysiology. In normal muscle development, muscle units called sarcomeres are grouped to make myofibrils which are in turn grouped to make fascicles. Bundles of fascicles make up skeletal muscles. In Cerebral Palsy, deficiencies reported with gait are fundamentally caused by issues in force production. Upon examination of ultrasonography, muscles in individuals with CP are shown to be much shorter. This causes a subsequent lack not only in force generation but also in muscle coordination (Mathewson et al., 2015).

There are 4 categroizations of CP: spastic, dyskinetic, ataxic, and mixed. All are caused by damage in specific brain areas. Spastic, the most common type, demonstrates exagerated movements and stiffness on one side of the body. Those with spastic CP also have difficulty with standing and walking, since they have limited balancing capability in their arms (due to flexion), as well as flexion at the knees and adduction of the thighs. Dyskinetic CP is characterized by slow and repetitive involuntary movements. It can be affected by one part of the body or the whole body. Ataxic CP, one of the more uncommon types, is identified through tremors and shakiness, poor balance (leading to difficulty in walking), and poor depth perception (Matthewson & Lieber, 2015).

With proper training, studies have shown that there is a possibility for those with Cerebral Palsy to regain some range of movement with repetitive exercise and training through physical therapy (Afzal & Manzoor, 2019). Those with cerebral palsy require intense training and performance of repetitive movements in order to form “muscle memory” and be able to perform certain movements on their own, without aid. According to Hsu et al., “intensive training” is defined as 4-6 hours per day over 4 weeks required in order to see results of improvement in motor functions. In general, exercise, or any form of physical activity is required to maintain a healthy lifestyle. For those who suffer from CP, performing certain types of exercises and movements during physical therapy training have been reported to help alleviate pain, prevent progression of the disease (beginning with skeletal and muscle structure, leading to maintenance of organs), and improve overall quality of life (Damiano, 2006).

Current Treatments/Preliminary Studies

Physical therapy is currently the best viable option for treatment of Cerebral Palsy. Although there are medications to treat spasticity that comes with CP, they are merely used to alleviate pain symptoms or manage movements. Some of these medications include antidepressants, antispastics, anticholinergics (for uncontrolled body movements) and anticonvulsants (to treat accompanying seizures) (*Medication and Drug Therapy*). Surgery, which is highly invasive, is another alternative for treating certain types of cerebral palsy. One common procedure done is known as Selective Dorsal Rhizotomy (SDR). The goal of this surgery is to reduce spasticity in children with CP (which is due to high muscle tone) by removing abnormal nerve fibers, and relax the muscle tone. This method has proven to be effective, however, it still must be coupled with continued physical therapy treatment (Westbom et al., 2010).

Physical therapy allows a patient to build up the strength in their muscles that do not function as well, and put them into practical use. Strength training used to be thought of as ineffective, but multiple studies have proved that myth wrong. One study in particular, compared the progression of strength and function in children with CP. Children were split into two groups and underwent strength-training treatment and usual physical therapy treatment for lower limbs. The training occurred over 12 weeks in groups of 4 or 5. Evaluations of progression in gross motor function, walking ability, strength, and overall mobility took place before, during and after treatment. The results of this study showed that the added component of strength training showed improvement in all areas tested when compared to normal care (Scholtes et al., 2008).

One of the oldest forms of CP physical therapy is using what is known today as the TheraSuit or Adeli Suit. These suits are comprised of a vest, arm and leg bands, shoes, and other body gear, all attached to bungee-like cords. This method allows the patient and therapist to work together to complete resistance training, and therefore increase the child's muscle strength (Martins et al., 2015). Aside from getting assistance from someone to move a limb, or use a means of support to help develop balance, there are devices and machinery built specifically for the purpose of rehabilitation of these factors. Recently, technology has begun to be incorporated in physical therapy in order to provide guidance of movements, track progress, and allow for interaction and feedback for the patient. Examples of these new advancements include a robotic arm that guides the user's movements in certain directions while having to complete a video game (Schneider, 2014). Over time, the robotic arm will no longer guide and will require the patient to move the device on their own. This specific model's goal is to strengthen neural connections of muscles. However, there are similar devices that have the goal of strengthening muscles in mind, such as treadmill training (Schuyler, 2006). Wearable technology has also become a new approach to rehabilitation, since it is able to directly measure and record movements of the patient (generally using 3D motion capture) while wearing the device, which allows for more personalized and targeted use (Jette, 2019).

Research Design and Methods

Our research design is focused on helping those with all types of cerebral palsy not only work to maintain balance but also to help develop significant motor function. Our device is modeled after that of an arcade game that similarly helps engage the participant in using the same muscles implicated in CP. We also recognize that our device is mainly geared toward children, as we have included the additional dimension of game play in order to engage the child and display self-motivation in participating in their treatment. This device will also be made to comfortably fit in a patient's house so that not only will the device be easily accessible to them, but also will be prompted to employ the use of the device more often and make more progress in a shorter time frame.

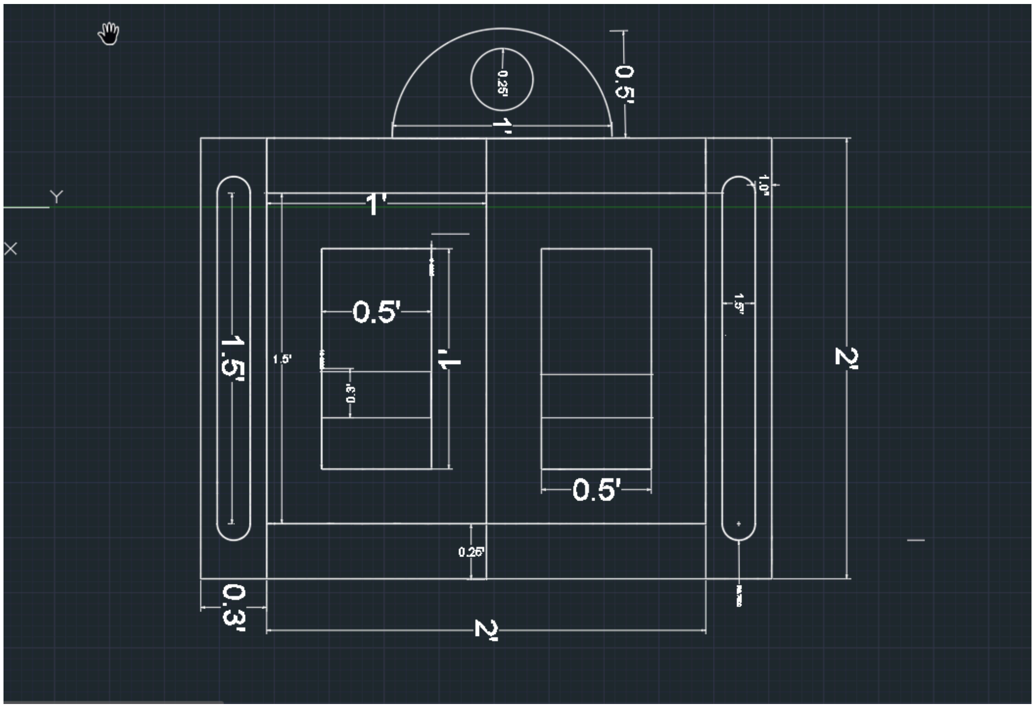

Fig. 1: An 2-dimensional AutoCAD drawing of our hypothetical design with appropriate dimensions in ft.

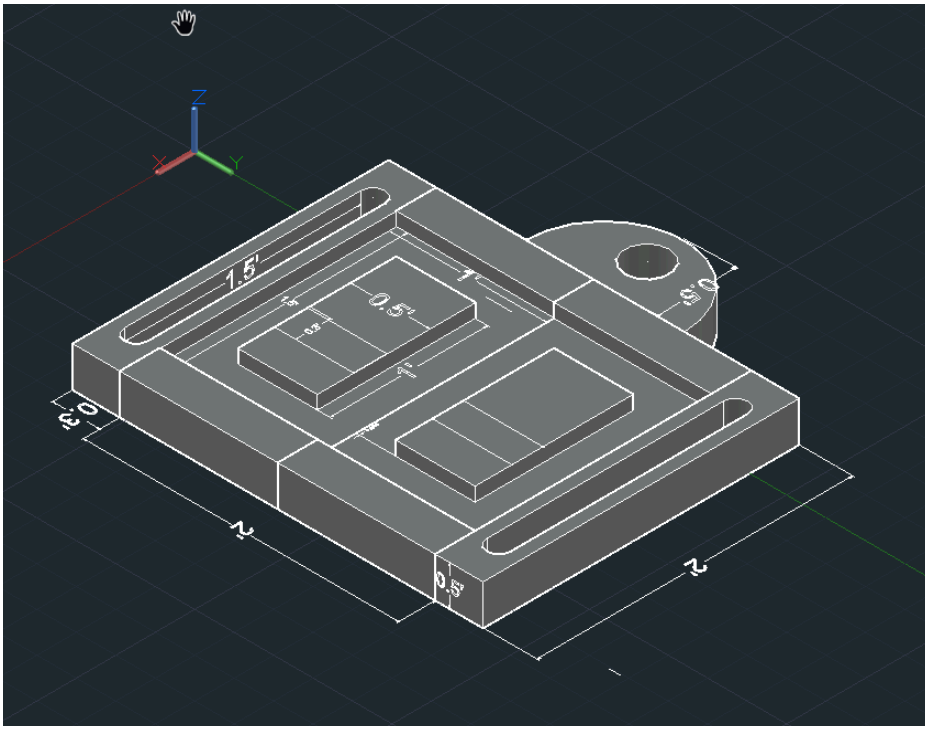

Figure 2: A 3-dimensional AutoCAD drawing of our hypothetical design excluding the additional components with appropriate dimensions in ft.

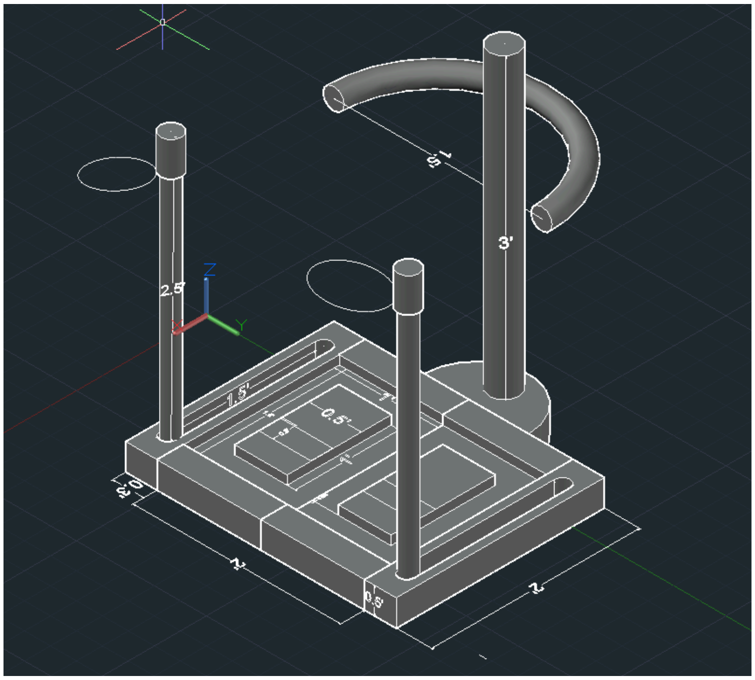

Figure 3: An 3-dimensionalAutoCAD drawing of our hypothetical design with additional components with appropriate dimensions in ft.

The design consists of a platform with seperate sliding platforms for foot placement, and a strap to hold in the patient's feet. The device can be used either while standing up or sitting down. This will be detected using weight/force sensors. If used while sitting down, less force will be used by the machine to move the feet in the controlled directions, since there is less weight applied. If used while standing up, the device will detect that there is more weight being applied, and therefore use more required force to move the user's feet. Since the patients using this device do not have a great ability to balance, the machine will contain a detachable back support (in order to use it while sitting or standing). The back support piece is able to be adjusted based on height. A seatbelt will secure the child into a comfortable position. There will also be arm support (poles, similar to crutches) that will be attached to the sides of the platform and will lock into certain positions depending on the patient's level of comfort; meaning how far or close they need the arm supports to be in order to use the device comfortably. There is an arm band that the child can insert their wrists/arms into in order to minimize spastic movements that often come with cerebral palsy. The armrests are adjustable in terms of not only location but height as well.

The directions the platforms will move in are left, right, back, and forth, since those are the typical basic movements that are targeted in these types of devices to stimulate the user's nerves as well as apply force of movement to their feet and legs. The device will begin by controlling the patient's leg and foot movements since this may be new to them. Once the user is more comfortable and gains the ability to be able to replicate the targeted movements, the device will control the patient less and allow the user to move their legs and feet in the proper directions. The machine will still continue to guide the patient, and make sure they are not falling off the projected path of movement, while giving them some independence to practice basic movements on their own. The device will have the ability to track the patient's progress and adjust how much control it has or does not have to apply over the patient's movements based on their progress. Of course, this is not a progression that can be made overnight, as it does take time for the patient to get used to the device and learning the proper gestures and movements.

The video game component of this design is merely used to engage the patient in having them want to do their required exercises. The game will be specific to the movement of the board. The progress the patient makes by using the machine will be detected by sensors in the platform. The video game is able to connect to the device via Bluetooth and sync with the progression of the patient recorded by the sensors in the platform of the device and level up accordingly. Some potential games could include soccer or skiing. This added gaming element will entice the children to want to perform their exercises while simultaneously motivating them to work harder in trying to complete a level.

Our primary material of use in constructing this device will be hard plastic both for durability and accessibility of the supply. The platform that the patient stands on will be made out of high density polyethylene with dimensions of 2'x 2.6'. Polyethylene is a good choice for our device due to the fact that it is sturdy and able to support a lot of weight, like a lawn chair or a plastic crate. The foot placements, however, will be made of aluminum since it seems most objects such as weight scales or anything used to detect weight or force, and support a heavy amounts of weight, is made out of some type of lightweight metal (Science Direct: *Crutch*, 2006-2019). The compartment housing the circuits and wires will be made out of stainless steel in order for the electricity to be easily conducted to the aluminum of the moving footrest. Additionally, on top of the lightweight aluminum there will be a silicone coating due to its flexible and non-slippery properties on the foot pads where the child is to stand. There will be a velcro strap over the foot indents to secure the foot in place and make sure it does not slide out of the appropriate area. The arm supports will be made of adjustable 3' aluminum poles since it is more rigid and needs to support the applied weight from the patient. The locking method for the arm supports will also use aluminum. The torso support will be made of a 3' adjustable aluminum pole with a polyethylene backrest and a velcro strap wrapping around the patient to secure them while using the device standing up. The arm supports will also contain a cushion-type of material to allow for comfort while the user is holding on to them.

Safety regulations that must be considered for this device include how sturdy it is, how much force will it use when moving the patient's legs and feet, and how much weight it can support. Since this device is targeted primarily to children, the maximum weight it needs to support is about 200 lbs. The force required to move the patient's legs and feet won't need to be that much stronger either. The platform must be sturdy enough that it will stay still on hardwood floor or carpet (depending on the location of the device), and not shift. The arm supports must remain in proper position when being used, therefore a locking mechanism is required to be placed on the sides of the platform to ensure the supports will not shift. The back support will be rigid, at the height of an average child with CP. Additionally, since the device does involve electricity it is important that the child is protected from being shocked. Therefore, putting silicone on the moving foot portion not only adds comfort but since silicone cannot conduct electricity, it will absorb any potential harm to the patient's feet. These safety regulations are put into place in order to ensure that the device will not cause harm to the child while it is being used.

Experimental Design

Our experimental design will test the hypothesis that our device will have significant results in patients in terms of balance and muscle movement in the same timeframe as compared to the results achieved by a gold standard device, since our device can be used in preferred location and on a personal schedule. To conduct this experiment, four groups will be created based on random assignment, two positive controls and two negative controls. For the positive control groups, one group will be using the gold standard of treadmill resistance training (Damiano, 2009). Treadmill training for cerebral palsy patients has been proven to be efficient in increasing walking ability after just walking on a treadmill for 6 minutes (Kim et al., 2015). The other will be using our device. The negative control groups will consist of one group that receives no physical therapy treatment, and the other group will be using our device without the video game component. This will also be testing whether or not it is required and efficient in keeping the child engaged in the rehabilitation process.

Each group will consist of 4-5 children in order to give individualized attention to each child and record their progress meticulously. The classifications of motor function for each child will be determined by using the Gross Motor Function Classification System, which is considered a standard method of classification across multiple types of studies of cerebral palsy (Wood & Rosenbaum, 2000). The participants must all have the same skill set level, in reference to how much ability in lower limb movement they all have. However, the type of CP the patient has will not matter, as balance coordination and movement are a deficiency present and common in all types of CP. The patients must also be on the same or similar types of medication, or no medication at all.

The participants will train on their respective devices for the recommended amount of training time (4-6 hours per day). The time frame for this study will be around 6 months, in order to be able to record significant results. The patients' progress will be recorded through the device itself (for those using our device) which will be able to quantitatively track the patients' development. We can also track who is able to move the foot pad using their own force, without complete assistance of the forces of the device. However, since the treadmill does not contain the technology that is implemented in our device, a double-armed goniometer will be used to measure the angle of how far the patient can move their legs for both the positive and negative control groups. These assessments will be done before treatment starts in all groups and measured at the end of every week, as well as at the end of the experimental trial period.

Results

The results of this experiment are to be measured by a trained professional in the field of physical therapy, specifically for cerebral palsy. This is to ensure that accurate measurements and conclusions are made. An ANOVA test to compare all 4 groups as well as a T-test to compare the two positive controls and the two negative controls will be performed to compare the statistical differences between the tested groups. The goal is to get a p-value less than .05 to be considered statistically significant. The results are likely to show that our device shows significant improvement in lower limb coordination since it consists of muscle strength and muscle memory building. The results will also be significant since it will be done over the recommended time frame that is considered intensive training of building muscle strength (Anttila et al., 2008). A study that tested treadmill training for a 3 month period, 25 minutes a day for three days a week found that motor movement and walking ability in children with cerebral palsy increased by about 47-50%, although they still continue to require assistance while walking. The children tested were also reported to be able to stand up on their own after their therapy treatment (Schindl et al., 2000). Based on these results, we expect our device to meet or exceed these standards, since our device includes various, beneficial components. The percent increase in motor functioning is based on the child's score/placement on the Gross Motor Functioning Classification System for Cerebral Palsy.

The results seem expected since they contain elements of existing devices, such as braces (in our case, the foot pads guide movement while the braces on the treadmill help keep the patient's feet in position to follow the directed movement) and sensors to track progress of movement (this is seen in wearable technology). This is profoundly helpful, since as mentioned earlier, cerebral palsy affects individuals in very distinct ways. The video game component of our device seems to be effective as well since previous results of studies have shown that including a video game component in lower-limb physical therapy rehabilitation has proven to increase the intensity and engagement of the child during their rehabilitation sessions (Robert et al., 2013). Being able to provide this individualized feature of tracking a patient's progress within the device only adds another helpful dimension to a patient's treatment plan.

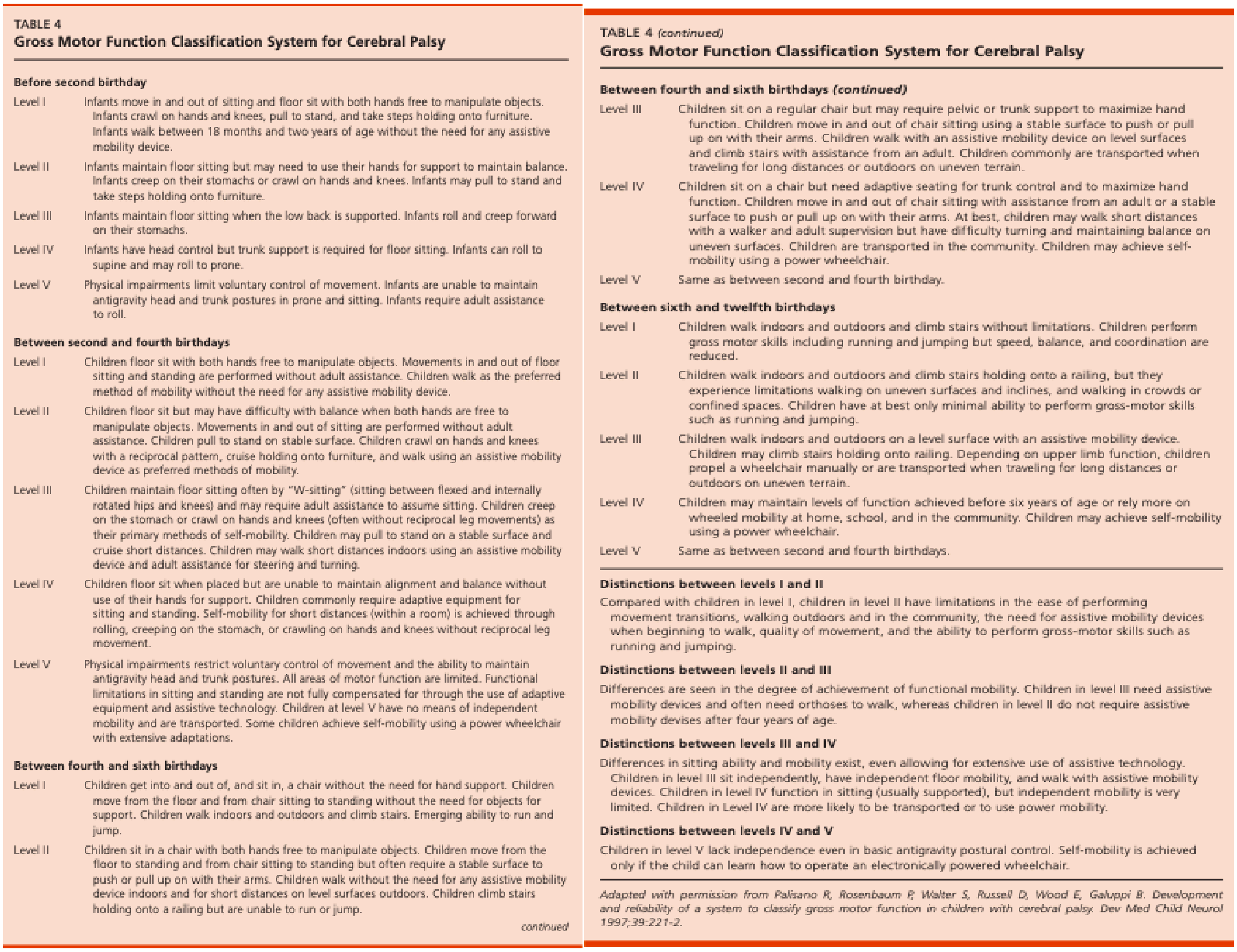

TABLE 4

Gross Motor Function Classification System for Cerebral Palsy

Before second birthday

Level I	Infants move in and out of sitting and floor sit with both hands free to manipulate objects. Infants crawl on hands and knees, pull to stand, and take steps holding onto furniture. Infants walk between 18 months and two years of age without the need for any assistive mobility device.
Level II	Infants maintain floor sitting but may need to use their hands for support to maintain balance. Infants creep on their stomachs or crawl on hands and knees. Infants may pull to stand and take steps holding onto furniture.
Level III	Infants maintain floor sitting when the low back is supported. Infants roll and creep forward on their stomachs.
Level IV	Infants have head control but trunk support is required for floor sitting. Infants can roll to supine and may roll to prone.
Level V	Physical impairments limit voluntary control of movement. Infants are unable to maintain antigravity head and trunk postures in prone and sitting. Infants require adult assistance to roll.

Between second and fourth birthdays

Level I	Children floor sit with both hands free to manipulate objects. Movements in and out of floor sitting and standing are performed without adult assistance. Children walk as the preferred method of mobility without the need for any assistive mobility device.
Level II	Children floor sit but may have difficulty with balance when both hands are free to manipulate objects. Movements in and out of sitting are performed without adult assistance. Children pull to stand on stable surface. Children crawl on hands and knees with a reciprocal pattern, cruise holding onto furniture, and walk using an assistive mobility device as preferred methods of mobility.
Level III	Children maintain floor sitting often by "W-sitting" (sitting between flexed and internally rotated hips and knees) and may require adult assistance to assume sitting. Children creep on the stomach or crawl on hands and knees (often without reciprocal leg movements) as their primary methods of self-mobility. Children may pull to stand on a stable surface and cruise short distances. Children may walk short distances indoors using an assistive mobility device and adult assistance for steering and turning.
Level IV	Children floor sit when placed but are unable to maintain alignment and balance without use of their hands for support. Children commonly require adaptive equipment for sitting and standing. Self-mobility for short distances (within a room) is achieved through rolling, creeping on the stomach, or crawling on hands and knees without reciprocal leg movement.
Level V	Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. Children at level V have no means of independent mobility and are transported. Some children achieve self-mobility using a power wheelchair with extensive adaptations.

Between fourth and sixth birthdays

Level I	Children get into and out of, and sit in, a chair without the need for hand support. Children move from the floor and from chair sitting to standing without the need for objects for support. Children walk indoors and outdoors and climb stairs. Emerging ability to run and jump.
Level II	Children sit in a chair with both hands free to manipulate objects. Children move from the floor to standing and from chair sitting to standing but often require a stable surface to push or pull up on with their arms. Children walk without the need for any assistive mobility device indoors and for short distances on level surfaces outdoors. Children climb stairs holding onto a railing but are unable to run or jump.

continued

TABLE 4 *(continued)*

Gross Motor Function Classification System for Cerebral Palsy

Between fourth and sixth birthdays *(continued)*

Level III	Children sit on a regular chair but may require pelvic or trunk support to maximize hand function. Children move in and out of chair sitting using a stable surface to push or pull up on with their arms. Children walk with an assistive mobility device on level surfaces and climb stairs with assistance from an adult. Children commonly are transported when traveling for long distances or outdoors on uneven terrain.
Level IV	Children sit on a chair but need adaptive seating for trunk control and to maximize hand function. Children move in and out of chair sitting with assistance from an adult or a stable surface to push or pull up on with their arms. At best, children may walk short distances with a walker and adult supervision but have difficulty turning and maintaining balance on uneven surfaces. Children are transported in the community. Children may achieve self-mobility using a power wheelchair.
Level V	Same as between second and fourth birthday.

Between sixth and twelfth birthdays

Level I	Children walk indoors and outdoors and climb stairs without limitations. Children perform gross motor skills including running and jumping but speed, balance, and coordination are reduced.
Level II	Children walk indoors and outdoors and climb stairs holding onto a railing, but they experience limitations walking on uneven surfaces and inclines, and walking in crowds or confined spaces. Children have at best only minimal ability to perform gross-motor skills such as running and jumping.
Level III	Children walk indoors and outdoors on a level surface with an assistive mobility device. Children may climb stairs holding onto railing. Depending on upper limb function, children propel a wheelchair manually or are transported when traveling for long distances or outdoors on uneven terrain.
Level IV	Children may maintain levels of function achieved before six years of age or rely more on wheeled mobility at home, school, and in the community. Children may achieve self-mobility using a power wheelchair.
Level V	Same as between second and fourth birthdays.

Distinctions between levels I and II

Compared with children in level I, children in level II have limitations in the ease of performing movement transitions, walking outdoors and in the community, the need for assistive mobility devices when beginning to walk, quality of movement, and the ability to perform gross-motor skills such as running and jumping.

Distinctions between levels II and III

Differences are seen in the degree of achievement of functional mobility. Children in level III need assistive mobility devices and often need orthoses to walk, whereas children in level II do not require assistive mobility devises after four years of age.

Distinctions between levels III and IV

Differences in sitting ability and mobility exist, even allowing for extensive use of assistive technology. Children in level III sit independently, have independent floor mobility, and walk with assistive mobility devices. Children in level IV function in sitting (usually supported), but independent mobility is very limited. Children in Level IV are more likely to be transported or to use power mobility.

Distinctions between levels IV and V

Children in level V lack independence even in basic antigravity postural control. Self-mobility is achieved only if the child can learn how to operate an electronically powered wheelchair.

Adapted with permission from Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol 1997;39:221-2.

Figure 4: A table of the Gross Motor Function Classification System for Cerebral Palsy. Adapted from (Krigger, 2006).

Discussion

Our device has combined many aspects and analysis methods that are currently used in physical therapy treatment for cerebral palsy to evaluate walking, lower limb movement, and balance coordination, such as force platforms and foot pressure (Agarwal & Verma, 2012). Our design seems to follow ergonomic principles, as it can be used at the patient's comfort level, whether they decide to use it while sitting down or standing up. The device also allows for the patient to continue their intensive training in the setting of their choice, as it does not require much outside assistance to use and operate. Currently, many children receive physical therapy treatment in their school setting. Studies have shown that once they are out of a school environment, it is very unlikely that patients willingly return to a physical therapy center to continue their treatment (Liljenquist et at, 2018) as it is time consuming and expensive. Therefore, it is important that our device is able to be used in a setting the patient is comfortable in. This provides another reason why it is important that our device is affordable and made with lightweight materials, in order that it can be an “at home” device. The weight limit of 200 lbs on our device is an overestimation. Additionally, while our device does not have a specific age requirement, it does have a maximum height of 3 feet for the torso support, therefore the age of the child or even teenager is not as important as their height, since children with cerebral palsy typically have height deficiencies in addition to being underweight (Strand et al., 2016). Other devices such as the treadmill does not have any height requirements, therefore increasing the maximum height for the device may be something to add in the future. The video game component of our device helps to fulfill the aim of having a device that is enjoyable, and according to some studies, this type of computerized training has become practical and helpful for children with cerebral palsy. It focuses the patient’s attention to a screen, which, if standing or sitting, requires keeping the head and body upright, controlling and maintaining good posture and balance (Pin, 2019).

One fault in our design is unlike the treadmill method or the TheraSuit; it does not contain a resistance training component, which is one of the key factors in building muscle strength (Damiano, 2009). A profound benefit of our device however is that it can be used by anyone with any type of CP, no matter the severity of their condition. Some devices, such as the TheraSuit for example, have limitations as to who may use this rehabilitation device based on the severity of their particular condition. A fault in our experimental design includes not using patients with a specific type of CP. Rather, we grouped the participants based on their Gross Motor Function Classification score. The experiment also compared devices with varying components, which may skew the predicted results.

Our device is only able to target the secondary symptoms of cerebral palsy, since it stems from prenatal brain injuries, which is currently not in the possible range of being able to be directly treated or cured. There are many viable physical therapy treatments available for CP, and therefore it is difficult to target a specific gold standard device, as well as an overall gold standard device for the treatment of cerebral palsy. This is also difficult to target since CP has many varying factors that need to be taken into account when determining an efficient device that can be used for rehabilitation (Vargus-Adams, 2009).

Conclusion

Cerebral Palsy manifests itself as distinct symptoms but contains similar patterns of motor function and balance coordination deficiencies. Our focus is to make a versatile device that encourages patient initiative in re-developing their motor function and balance coordination. Our device can be proven to be beneficial for individuals with CP when compared to similar devices by helping the patients build up strength in their muscles as well develop muscle memory for how to recreate these movements. The ability to build up strength also provides the added benefit that it also re-develops muscle-neuronal connection, allowing for faster reaction time and increased speed when prompted to display a certain motion. In the future, we would look out toward building upon the features our current design has and including additional components that add a resistance factor to our device.

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