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DESIGN OF AN ASSISTIVE-REHABILITATIVE WALKER FOR CHILDREN WITH CEREBRAL PALSY

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ABSTRACT

Cerebral palsy (CP) is a disorder which is caused by brain damage. Most of the cerebral palsy children cannot walk on their own. They need an assistive or rehabilitative walking device to help them to walk, however most of these devices are either single- functional and/or expensive. This paper describes the design of a multifunctional and relatively affordable assistive-rehabilitative walker. The design requirements were developed from discussion and interview with CP children and their caregivers. The designed walker has four configuration modes which are standing and walking mode, ground-sitting mode, wheelchair mode and exercise mode. Analysis was conducted to ensure the design is safe to be used, and the design was fabricated. The fabricated prototype was tested with a cerebral palsy child. Four different tests were conducted with the prototype where the child managed to use the walker for the intended purposes.

Keywords: cerebral palsy, assistive device, rehabilitation device.

INTRODUCTION

Cerebral palsy (CP) is a common term used to describe a group of chronic conditions affecting muscle coordination and cause disabilities mainly in the areas of body movement due to non-progressive lesion or injury to immature brain of a child (Hauser, 1993). Cerebral palsy is the leading cause of developmental disability in children (Neufeld, 2011). The incidence of cerebral palsy is between 2 to 3 per 1000 live birth (Reddihough, 2003). Of these affected, one-third are mentally retarded, one-third are capable of considerable improvement, one-sixth are so mildly affected that treatment is not necessary and one-sixth are so severely affected as to be bedridden (Silver, 1975). Cerebral means cerebrum which is a part of brain that affected. For the cerebral palsy case, the affected parts are cerebellum and cortex. Palsy is a term used to refer paralysis (Rosenbaum, 2006). Cerebral palsy is a permanent disability; however the disability can be improved by proper treatments such as physical and occupational therapy (O'Shea, 2008).

Some cerebral palsy children cannot walk on their own (Freeman, 2005). They need an assistive or rehabilitative walking device to help them walk properly. There are several problem were identified in current walking devices available in market. First of all, they are not widely available and most of the walking devices for cerebral palsy are relatively expensive for an average income family with CP child. Another problem is walking devices are having single function. For an example, a walking assistive device only can assists a child to walk but it cannot be used as a rehabilitative device.

Cerebral Palsy (CP) is a disorder which caused by brain damage. This disorder affects movement, muscle tone and motor skills .Patients with CP normally will have abnormality in visual, hearing, learning, epilepsy, speech and some of them are intellectually challenged (Marzieh, 2012).

CP can be categorized into 3 major types which are spastic, dyskinetic and ataxic. Spastic is the most common type. Patients with spastic CP develop tight muscle in some parts of body. Usually, they cannot move properly because of poor coordination. Most of the cases they cannot move leg and arm on the same side of body or both legs.

Dyskinetic CP is related to muscle tone which get loose and tight irregularly. Patients with this type of CP cannot control their movement; it's out of their control. We can see their involuntary movements when they trying to move. Some of the examples of dyskinetic CP are unusual facial expressions, drooling, speaking, and choking. The third type is ataxic which is the rarest. People with ataxic CP will face disturbed sense of balance and depth perception. They cannot have precise movement. For example, they may reach too close or too far to touch objects (Sangkar, 2012).

Cerebral palsy also can be categorized using gross motor function classification system (GMFCS). There are five levels of classification system in GMFCS. First level of GMFS includes the children and youth with cerebral palsy who can walk without any limitation. Second level patients face problems or limitation in walking long distance and balancing. In level three, the patients need assistive devices such as cane, walker and crutches to walk. Patients with fourth level cannot walk on their own; they need a manual wheelchair or a powered mobility device to get transported to another place. Those in fifth level are consider as critical level because they have limitation in head and trunk control and need advance technology and physical assistance (Silva, 2013).

Children with cerebral palsy will face problems with movement coordination. There are many rehabilitative devices invented to help them. Rehabilitative devices are devices that can help a person function better and be more independent. The most suitable rehabilitative device for this project is walking device or walker because this project is specifically for children with walking problem.

Walking device, categorized under assistive device, can aid a person to walk and at the same can help to improve his mobility. There are various types of walking devices and walker including canes, mobile walking aid devices, and wearable walking devices. Each walking devices has its own specifications. Not every patient can use every walker; it depends on patient's conditions and their disability. Each type is varying by price, material used, working principle, technology level, safety level and mobility level.

The main aim of the research is to design a hybrid or integrated device that can function both as an assistive and rehabilitative device.

DESIGN

The requirements

The requirements need to be established before the design work is carried out. This was done by carrying out discussion and interviews with relevant parties including the parent and caregivers of CP children as well as the medical personnel.

Based on these, the requirements are listed down and grouped into three categories, which are: functional, safety and engineering requirements. The following requirements are listed under functional:

- The design must be multifunctional, where the device can be reconfigured for different required functions.
- The target users are children with CP categorized under GMFCS level II or III. These children have ambulatory capability but requiring assistant in standing and walking. They also require frequent walking therapy.
- The device is intended to be used indoor, mainly at home.
- The device should be relatively mobile and easy to be transported around.
- The device must be comfortable to be used.
- Aesthetically pleasant

For safety requirements, the following requirements are listed:

- Must not topple during operation.
- Must provide stability during standing and walking
- Using child-safe material and finishing, non-toxic and also environmentally friendly.

For engineering requirements, the list is as below:

- The cost should be affordable for a family with an average income.
- Easy to be reconfigured.
- Strong and robust to support the intended usage.

Anthropometric measurement

Anthropomentri measurement was taken to obtain the range of size or length of relevant limbs. A survey on the weight and height was also done on Malaysian children with CP condition. A total of 25 CP childen were measured. Table-1 shows the range of weight and height of these children.

Table-1. Weight and height range.

Age range	Weight range (kg)	Height range (mm)
4 - 12	15 - 47	94 – 130

Design concept

Based on the requirements, the design concept was produced. It is the main intention to make the design as simple as possible while fulfilling all the requirements. The first design concept is as shown in Figure-1.

The main structure is the slightly slanted bar, also called the spine, provides the support where other parts are attached to it. The seat is attached to the spine and can be adjusted in height. The handle bar can be swung forward and backward to provide hand support for the child. The base consists of three legs, which are detachable.

Figure-1. The first design concept.

After further evaluation and refinement, the concept was improved as shown in Figure-2. The design is generally made to be much simpler. The legs are made to be horizontal for easier manufacturing, a spring-loaded pin is used to make the seat adjustment easier and the spine is made to be vertical.

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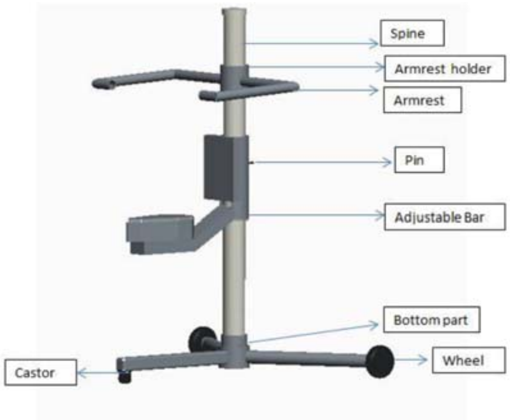

Figure-2. The refined design.

The different configurations or modes are as shown in Figure-3. The first mode (a) is where the child could use the device to assist in standing and walking. When he or she gets tired, he/she can use the seat to rest. The child can carry out other exercise such as sitting-and-standing to strengthen the arm muscle. The second mode (b) is the pushing mode. If the child is strong enough, he/she would stand at the back, pushing the device while holding the arm rest for support. The third mode (c) is used for floor activity. The child can sit on the seat while able to manipulate items on the floor.

(a) (b) (c)

Figure-3. Different configuration modes.

Analysis

There are eight major parts in this design which are the adjustable bar, spine, pin, armrest, armrest holder, bottom part, castor and wheel. Four critical parts were identified and stress analysis was carried out. The identified critical parts are pin, bottom part, armrest and seat. Based on the analysis result the factor safety has been calculated for these parts.

The stress analysis was conducted used a 3D modeling and analysis software. It is assumed that the weight of the user is 500N.

The first critical part is at the pin because the pin is holding the adjustable bar at the locked place with the weight of user. Weight of the user and weight of the adjustable bar both are placed on the pin when the design is in use. It is assumend that the sum of user weight and the weight of adjustable bar is 700N acting vertically downward. The part where rod and pin are in contact is fixed as constraint. The result of analysis conducted is shown in Figure-4. From the analysis we can conclude the factor of safety is 2.28.

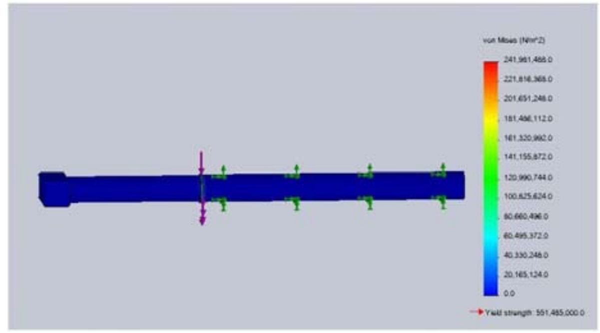

Figure-4. Analysis on the pin.

The second critical part is the seat. The weight of the user is applied directly on the seat when the user is in Sitting and Walking Mode. From the analysis conducted, as shown in Figure-5, we can conclude that the factor safety is 3.49.

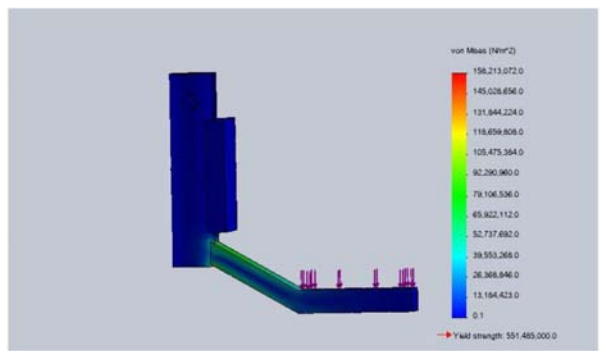

Figure-5. Analysis on the seat.

The third critical part is armrest. When the walker is in Wheelchair mode, the armrest is the part where the parents going to use to push the whole walker. Therefore, the whole force exerted by the parents will be applied on the handle of the armrest. From the analysis, we can conclude that the factor of safety is 3.31. The result of the analysis is shown in Figure-6.

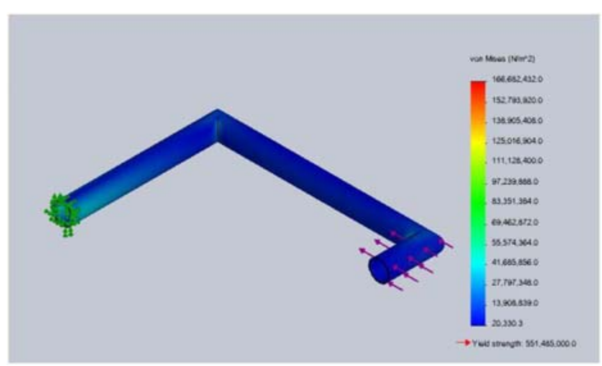

Figure-6. Analysis on the handle bar.

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The last part identified as critical is the bottom part. The weight of the whole system and the user will be applied on the bottom part. Therefore, it has a great chance to fail. Thus it has been overdesigned where thicker rod was chosen. Based on analysis, we can conclude the factor of safety is 7.05. Table-2 shows the summary of factor of safety for each critical part. From this, it can be seen that the design is safe.

Table-2. Summary of safety factor analysis result.

Part name	Safety factor
Pin	2.28
Arm-rest	3.31
Seat	3.49
Bottom/base	7.05

DISCUSSIONS

The design was fabricated and the result is as shown in Figure-11. The prototype is slightly different from the original design. An extendable leg rest is added to provide leg support for the user.

The protototype was then tested with a 9-year old quadriplegic cerebral palsy.

For the first test, sitting and standing mode was tested, as shown in Figure-7. At this testing, a quadriplegia child was brought to sit on walker. As a first step, the seat and arm rest was adjusted to the child's height. Then the child held on the handle bar in the standing position. She then sat on the chair while still holding the handle bar. This was repeated for about 2 minutes. By observation, we can see that the child were able to carry out the standing and sitting exercise without any problem.

Figure-7. Testing on sitting and standing mode.

For the second test, standing and walking mode was tested, as shown in Figure-8. For this test, the same quadriplegia child was brought for testing purpose. The seat part was removed from the walker because it would be a disturbance during the walking session. Then the height of armrest was adjusted to child's standing position. Then the child walked for about one meter with the walker using the armrest as a support. This test proved that the walker can be used for standing and walking mode.

Figure-8. Testing the standing and walking mode.

For the third test, 'parent-assist' or wheelchair mode was tested, as shown in Figure-9. For this test, the seat was reattached back to walker. The armrest was brought to backside and fixed there. The quadriplegia child sat on walker and the height of the seat was adjusted to child's sitting height. Then another able person was brought to push the walker. He pushed the walker for several meters while the child was seating on it. This test concluded that the walker can be used in wheelchair mode without any problems and obstacles.

Figure-9. Testing the wheelchair mode.

For the fourth test, the seat was lowered to the lowest position. This would allow the child to take and manipulate items on the floor. The handle bar was removed as to not obstruct the activities. This mode is as shown in Figure-10.

Figure-10. Floor sitting mode.

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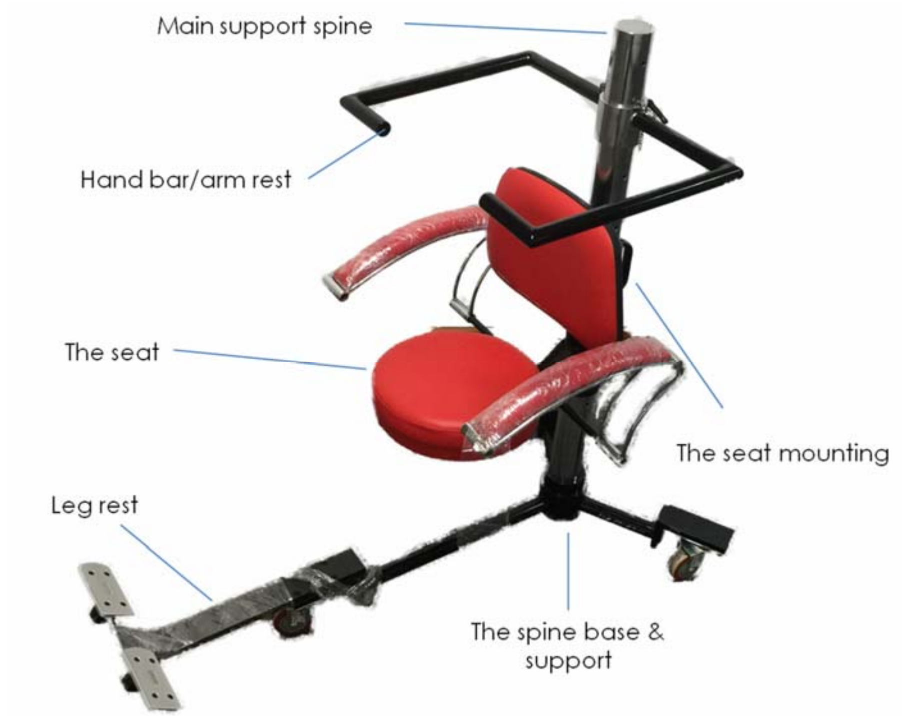

Figure-11. Fabricated prototype.

CONCLUSIONS

The main aim of the research is to design a device for cerebral palsy children that combine the assistive and rehabilitative functions into a single device. At the start of the design process, user requirements and inputs were acquired. Anthropometric measurements of CP children in Malaysia were carried out.

The device is designed to be multipurpose, where it can be reconfigured into four main functions: which are the standing and walking mode, the standing and sitting mode, the wheelchair mode and the floor sitting mode.

The design has been fabricated and the prototype was tested with a 9-year old quadriplegic CP child. The four different modes were tested and the results were very positive.

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