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DESIGN OF WEARABLE DEVICE TO ASSIST CEREBRAL PALSY CHILDREN IN STANDING AND WALKING

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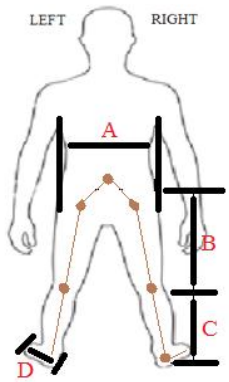
Graphical abstract



Abstract

Most children with cerebral palsy (CP) have difficulties in standing and walking. They would normally require assistive device to help in standing and walking. This paper describes the process that was carried out to design a wearable brace for the lower limb. This brace is intended to provide support during standing and walking for ambulant CP children. Design requirements were drawn up by conducting surveys and interviews with parents, CP child caregivers, and CP children. Safety is very crucial for the device, where special care is made to ensure it would not pose any hazard to the children and also the caregivers. Based on these information and the anthropometric measurements, the device has been designed and analyzed using 3D CAD software. From the analysis, the device shown to function as expected.

Keywords: Cerebral palsy, wearable device, lower limb

1.0 INTRODUCTION

Cerebral palsy (CP) is an umbrella term for neurological (motor) conditions that affect a child movement and coordination with wide spectrum of severity depending on type of CP a child is affected with. It is a non-progressive and congenital disorder. CP is the leading cause of developmental disability in children [1]. The incidence of CP is between 2 to 3 per 1000 live birth [2]. There is no cure for CP, however these children need to undergo physiotherapy throughout their lives to alleviate pain due to spasm or to certain extent, enable walking. Children with several types of CP have the ability to walk if gait rehabilitation is administered to them, preferably during childhood. This is due to neuroplasticity which is the ability of human brain to relearn lost or affected functions such as walking and standing through intensive and repetitive functional training.

Due to the conditions affecting them, CP children need assistance in standing and walking, to move around and conduct daily activities [3]. Also, they often have difficulties in maintaining proper body posture which need assistance as well to position their body properly. A wearable device is proposed for usage of ambulant CP children. The wearable device is expected to provide assistance for standing, walking, and posture correction.

For the design of the device, there are few requirements to be taken into account. The consideration of these requirements would determine the functionality of the device and better acceptance from target user. The requirements will be used as inputs to generate idea for the device. Then, modeling and stress analysis of the device is done using a commercially available 3D CAD software.

2.0 DESIGN REQUIREMENTS

Design requirements for the proposed assistive device were obtained through surveys involving appropriate parties. The requirements for designing this device consists of market requirements, anthropometric measurements of CP children, ergonomic requirements, and safety features. The market requirements can further be subdivided into 3 different aspects: functional requirements; user requirements; manufacturer requirements (Figure 1).

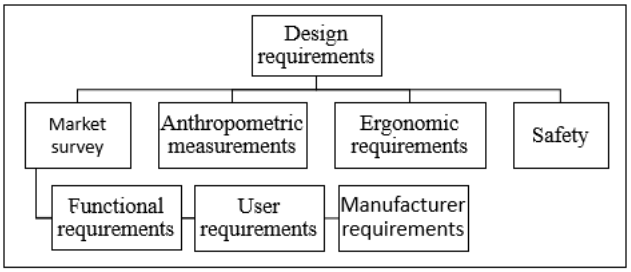


Figure 1 Subdivision of design requirements.

2.1 Market Surveys.

Currently, there are many assistive devices which are commonly used to increase, maintain, or improve functional capability (e.g. walking) for ambulant CP children such as reverse walker and ankle orthosis. Surveys were conducted by interviewing several parties such as the parents and caregiver of CP children, medical specialists, and assistive device manufacturers/fabricators to determine the requirements for functions, customer needs, and manufacturing of the device. The survey results are used to draw up the main design requirements, which are shown in Table 1.

2.2 Anthropometric Measurements

Dimensions and range of adjustability of the device depend largely on anthropometric measurements of target users (Fig. 2). The measurements were acquired from 25 CP children aged between 1 – 18 years old, of which only 6 subjects were ambulant. Due to difficulty of finding more subjects, we decided the data obtained would be sufficient for establishing the device initial dimensions. These dimensions will be further refined with respect to other aspects which will be presented in the subsequent sections.

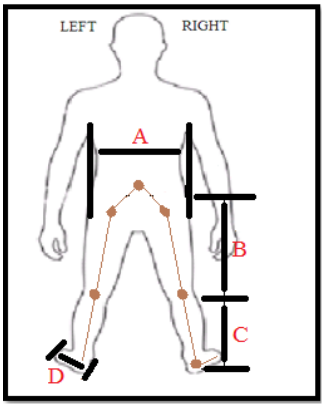


Figure 2 Required anthropometric measurements of target users.

Table 1 Main design requirements

Requirements	Aspects	Description
Functional	Correct posture	Posture correction assistance
	Support standing	Standing assistance
	Assist walking	Walking assistance
	Strength	Able to dupport body weight
	Structure	Wearable
	Stability	Provide stability
User	Weight	As minimum as possible
	Shape / looks	Attractive, pleasant, non-intimidating
	Color	Neutral, lokks nice on various clothes color
	Durability	Minimum 5 years
	Adjustability	Adjustable to user body
	Portability	Easy to carry, foldable
	User-friendly	Easy to wear
	Material	Anti-bacterial, durable, lightweight
Manufacturer	Cost	Keep as low as possible
	Time	Lower production time
	Production	Easy to produce, minimize fabrication

Table 2 Anthropometric measurements of target user: age 7 and 16 years old.

Measurement (cm)	Age		Difference (cm)
	7	16	
A	28	32	4
B	35	45	10
C	36	42	6
D	19	20	1

The measurements are tabulated to generate graphs and trend line equations. The equations will be used to determine differences of measurements of CP children aged between 7 and 16 years old. The differences in measurements are essentially the range of adjustability of the device. Anthropometric measurements of target user for age 7 and 16 years old which are shown in Table 2.

2.3 Ergonomic Requirements

Physical ergonomics of the device plays a vital role in assuring good acceptance of the device by the target users. Since the device is wearable, it must be comfortable enough to be worn for at least 4 hours, does not cause pain, and should minimize fatigue. Additionally, the device must be able to be washed or cleaned with minimal effort.

2.4 Safety Requirements

Safety is of utmost importance in designing devices with which humans will interact directly specifically for medical purposes. Hazards associated with usage of assistive devices were identified which will be used to generate mechanical solutions and safety features of the device. The processes involved are as illustrated in Table 3.

3.0 RESULTS AND DISCUSSION

3.1 Conceptual Design

Design requirements discussed in previous section will be used as design inputs for the proposed device. Idea generation was done through morphological analysis such as shown in Table 4. Morphological analysis method was chosen to systematically present the design possibilities of the proposed device. The first column of the table represents main functions of proposed device while the possible existing options were presented in the subsequent columns in Table 4.

From the analysis, we came up with several designs and the best solution was chosen. Referring to Table 4, the feature options for this device are as shown in bold boxes. This device is named "Wearable Brace CP – WebCP". Modelling of of WebCP is done using a commercially available Computer Aided Design (CAD) software. The initial design is as shown in Figure 3. From the analysis conducted using the software, the weight of WebCP is below 3 kg when aluminum is used as the material. The structures of WebCP will buckle under the load of 750 N (maximum weight of target users: 470 N), which is having a factor of safety of 1.6.

Table 3 Processes involved in designing safety features for device

Hazard	Solutions	Features
Falling	Lower center of gavity (COG) and increase base area of device	Device with lower COG and obtain larger base area using crutches or walker
Injury due to limbs range of motion (ROM)	Limit ROM of lower limbs according to values presented by Kadaba et al. [4]	Stops at device joints to limit ROM
Cuts	Eliminate sharp edges	Rounded or filleted edges
Body parts get caught between moving components of device	Isolate body parts from moving components	Covers for moving parts of device

Table 4 Morphological analysis for idea generation of device

Function	Option 1	Option 2	Option 3
Stability	Side stability support	Front and rear stability support	Walking base and frame
Body weight support	Overhead body harness	Waist / Torso support	Body / Shoulder strap
Walking and Standing assistance	Braces	Prallel bar	Walker
Body posture correction	Body strap and passive element	Posture correcting vest and passive element	Rigid back body rest with side support and body strap

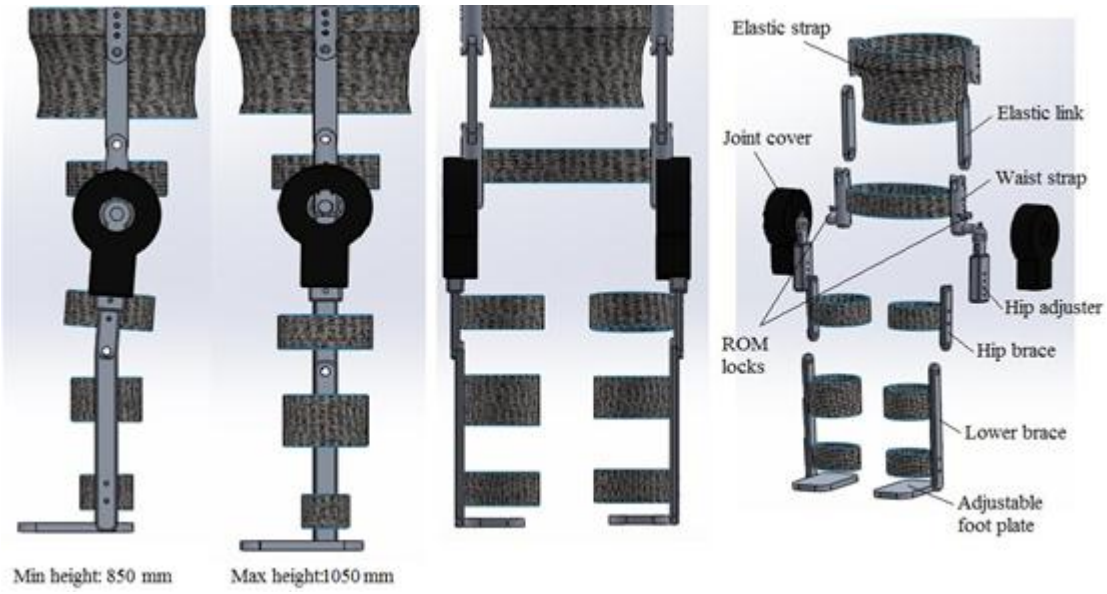


Figure 3 Wearable Brace CP – WebCP initial design

4.0 CONCLUSION

This research paper presents the initial design of wearable brace for CP children (WebCP) which involves obtaining design requirements through conducting surveys, then using the requirements as input and utilizing morphological analysis for idea generation. Initial design was modelled in CAD software and proof of concept was also done using the software. The initial design will be used as a foundation for development of this device into reality and evaluate its effectiveness by conducting experiments on ambulant CP children in near future.

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