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# A Simple Motorized Gait Trainer Using Fourbar Mechanism for Children with Cerebral Palsy

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**Abstract** – *Cerebral palsy (CP) is a condition that affects the physical movement of a person, including the ability to walk. Most of CP children have problem in walking, thus requiring frequent, intensive physiotherapy and training to improve their condition. A gait trainer is normally used to train or re-train a person on how to walk. This paper describes the process of designing a simple motorized gait trainer system for CP children between age range of 6 to 12 years old. The system consists of a treadmill, body support rig, wearable leg brace actuated through fourbar mechanism, sensors and electronic control unit. The design and analysis was carried out using Solidworks software. A scale down prototyped was produced as a proof of concept.* 

**Keywords**: Cerebral Palsy, Gait Trainer System, Rehabilitation Process

## 1.0 INTRODUCTION

This research is focused on designing a motorized gait or walking trainer system. The intended user of this system is children with cerebral palsy (CP). Cerebral palsy is a neurological condition that commonly affects the physical movement and mobility of the child [1]. CP is one of the leading causes of developmental disability in children [2].

As these children usually have problem with mobility from birth, they would require training on how to walk. The decreased in locomotor function would reduce their ability to move around and participate in daily activities [3]. Normal person would typically able to walk without needing to formally learn on the actual gait or walking pattern. In order to assist on gait training, special purpose devices or systems are used.

There are various types of devices used for gait training. One example is a simple parallel bar. Another example is a motorized of robotic-based gait trainer system. A motorized system usually consists of wearable attachment on the leg which is connected to an actuator. An advantage of using a motorized gait trainer system is that the walking pattern can be programmed and the system can replicate this motion thus moving the leg of the CP child according to the correct walking pattern. This will help to train the child by embedding the pattern of motion into the brain.

However, it is often difficult to get access to a motorized gait trainer system as it is extremely expensive and require high level expertise to use it, and only very few hospitals have this equipment in Malaysia.

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## 2.0 DESIGN

### 2.1 The Design Requirements

Firstly, the customers' requirements (CR) are established by discussion with relevant parties including medical doctors, physiotherapist, and parents or caregivers of CP child. The main requirements are described as followings:

- Safety
  The system must be designed with high safety in mind. Customers want a design or system that is safe to use especially for the motorized part, of the leg brace-actuator. As we will use motor for the leg actuator, motor and sensor selection must be done very carefully.

- Comfort
  Customers want the design to be comfortable to use, specifically in terms of the material use. For example, the body support rig, which includes the harness, must be comfortable to wear and the leg actuator must be fit nicely and can be adjusted according to the size of different children's legs.

- Ease of use
  The system that is designed must be easy to use. This is important as we focus on helping the target group to use this system even at their own house. The leg actuator and the treadmill, which are using sensor and motor, are controlled by a micro- controller. A proper guideline and a clear manual must be prepared for the user.

- Affordable
  The existing designs or products that are in market are very expensive. As one of the intentions of this system is to be used at home, the cost must be reasonable.

From the CRs, the engineering requirements (ER) have been established as followings:

- Geometry
  The target group of users is children with cerebral palsy with age of 6 to 12 years old. The size and geometry of the system must follow the appropriate anthropometric measurements. Based on prior survey, height range is 113 cm – 139 cm and the shoulder width range is 26 cm – 37 cm.

- Material
  The material chosen need to be strong enough to support the weight range of 20 to 50kg

- Safety
  Safety is very important for this project especially for the leg actuator, which involve motor and sensor. On the engineering requirements, we would require 3 levels of safety system for the leg actuator consisting of electronic-based sensor, mechanical limiter and fuse or current limiter.

### 2.2 Design Concept

Based on the CRs and ER, initial concept design has been developed. As shown in Figure 1, the design consists of four major parts, which are:

1. The treadmill
2. The body support structure with body harness
3. The motion linkage system with electronics control

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4. The wearable leg brace

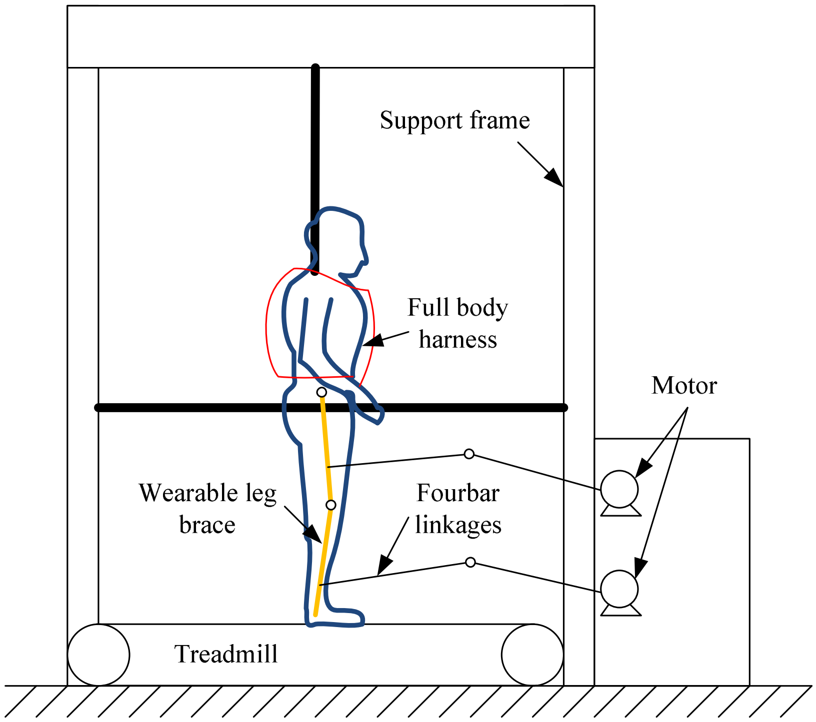


**Figure 1:** Concept sketch of the design

The body support structure consists of the steel frame with overhang body harness from the top. The harness is chosen because it will provide full upper body support. It is important for this component to sustain weight of maximum 50 kg for the target users. Besides that, the harness is has higher safety design compared to body straps and Y-shaped yoke.

For the walking assistive component, treadmill is chosen. This is because the treadmill will provide a constant speed motion and the speed can be adjusted to suits the person's ability. This is very important as different person has different pace and speed of walking.

Next is the lower limb support. Lower limb is covered from waist or human pelvis of a person to toe. Since the target group is people who are classified in Level 2 and Level 3 of the Gross Motor Function Classification System (GMFCS), the leg actuator without motor is good enough and it must be adjustable. This target group has the ability to walk but it is difficult for them.

Four sets of fourbar linkage or the 'robotic arms', which are driven by motors, will hold the leg actuator and thus provide the normal walking pattern. The motors will be programmed so that it will follow the normal walking pattern and will limit the movement at certain angle, depending on the ability of the users.

Lastly is the safety of the system, which is the most important factor. Two touch sensors are the first level of the safety system. Then, the mechanical limiters are placed at the waist and knee joints which will stop the linkages from overshooting its intended range of motion. Lastly the fuse or current limiter is placed in the control box. The walking pattern of normal

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person must be identified first. Then, the maximum angle is identified. Therefore, when something is wrong like the robotic arms move the leg actuator more than the maximum angle, the touch sensor, limiter will detect, thus the fuse will cut off the current supply.

Based on the initial sketch, a 3D design has been produced using Solidworks software, as shown in Figure 2. The main frame or support structure is intentionally designed to be as simple as possible, using hollow rectangular steel bar. The overall dimension is 2m (length) by 0.6m (wide) by 1.5m (height).

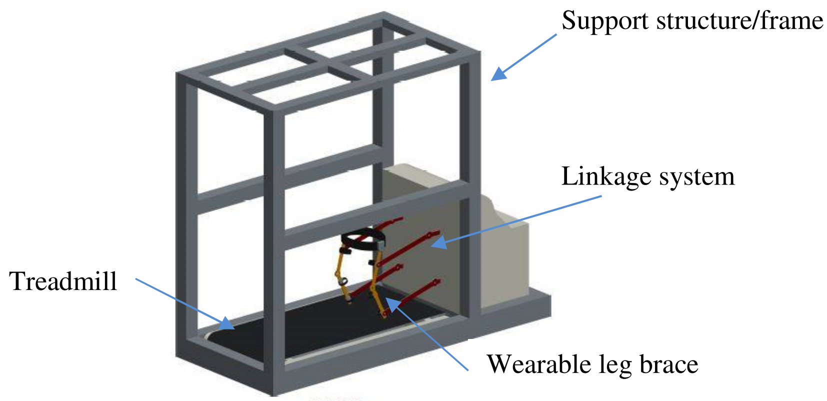


**Figure 2:** 3D model of the design

## 2.3 The Gait Pattern

The gait or walking pattern has been studied by capturing the motion of human walking. This is carried out by placing markers at three main locations, the hip, knee and ankle, and captured using video camera. Figure 3 shows the walking sequence. From this walking sequence, the swing angle has been measured as followings:
1. Point of rotation at waist = 38˚
2. Point of rotation at knee = 59˚

These two angles are important in determining the geometry of the wearable leg brace and synthesising the linkage for moving mechanism.

## 2.4 Leg Brace Design

Figure 4 shows the leg brace design. It is wearable to provide posture correction and also support during gait training. The brace bar is proposed to be made using stainless steel while cloth-based straps are used to attach to the legs and waist. In each joint, at the knee and waist, mechanical stopper is used to limit the range of motion. Touch sensors are also incorporated to add another layer of safety feature. These sensors will be programmed to detect the position of the bar.

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**Figure 3:** Capturing gait pattern


**Figure 4:** The wearable leg brace

Based on gait pattern data, the fourbar linkage is synthesised and the link length are determined. Fig. 5 shows the arrangement of the linkages and the attachment to the leg brace. A motor will be attached at the ground end of the fourbar linkage to provide rotational motion.

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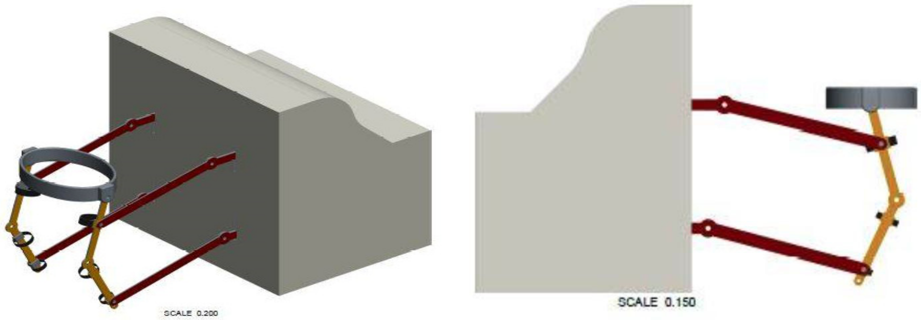


(a) Isometric view (b) Side view

**Figure 5:** The fourbar linkage

### 2.5 Fabrication

A scale down prototype, as shown in Fig. 6 has been fabricated to demonstrate the working concept of the design. PVC pipes were used to build the main frame of the support structure while a simple belting system is used to build the treadmill.

**Figure 6:** Scale down prototype

## 3.0 CONCLUSION

The main aim of this project is to design a motorized gait trainer system, which is to be used in rehabilitation process for children with cerebral palsy. There are three main functions of this system, which are to provide walking training or walking assistive, to provide upper body support, to provide lower limb stability and to ensure the whole system operates at highest safety.

A steel frame is proposed for the body support rig, attached with full body harness. A wearable leg brace is designed to be actuated by motors through fourbar linkages. The leg brace is integrated with safety features, including electronic touch sensors and mechanical limiter to ensure it can be used safely. A scale down prototype has been fabricated to demonstrate the main functionality of the design.

## ACKNOWLEDGMENT

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