WEARABLE WALKING AID FOR ELDERLY PEOPLE

By

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# TABLE OF CONTENTS

LIST OF ILLUSTRATIONS ............................................. ii

LIST OF TABLES ......................................................... v

Chapter

1. INTRODUCTION .................................................. 1

2. THE HEALTH OF ELDERLY PEOPLE ........................... 4

3. THE RESEARCH OF CURRENT WALKING AIDS ............ 7

4. CONCEPT DEVELOPMENT AND
   THE DESIGN PROCESS ........................................ 10

   Original idea and concept
   How to support
   The solution: electromagnets
   Walking cycle and postures
   The magnetic device
   The components and appearance of the walking aid
   Body measurements and human factors
   How to fit on the body
   The control
   About the walking aid

5. CONCLUSION ..................................................... 34

BIBLIOGRAPHY .......................................................... 36
**LIST OF ILLUSTRATIONS**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number of elderly people over age 65 in the United States</td>
<td>1</td>
</tr>
<tr>
<td>2. Number of elderly people over age 85 in the United States</td>
<td>2</td>
</tr>
<tr>
<td>3. Percentage of 65 years and older</td>
<td>2</td>
</tr>
<tr>
<td>4. Cane</td>
<td>7</td>
</tr>
<tr>
<td>5. Quad cane</td>
<td>7</td>
</tr>
<tr>
<td>6. Walk cane</td>
<td>7</td>
</tr>
<tr>
<td>7. Forearm Crutch</td>
<td>8</td>
</tr>
<tr>
<td>8. Axillary Crutch</td>
<td>8</td>
</tr>
<tr>
<td>9. Standard Walker</td>
<td>9</td>
</tr>
<tr>
<td>10. Front-wheeled Walker</td>
<td>9</td>
</tr>
<tr>
<td>11. Four-wheeled Walker</td>
<td>9</td>
</tr>
<tr>
<td>12. The robot designed by Honda Motor</td>
<td>10</td>
</tr>
<tr>
<td>13. Sketches of the original concept</td>
<td>11</td>
</tr>
<tr>
<td>14. Maglev train</td>
<td>14</td>
</tr>
<tr>
<td>15. How Maglev train works</td>
<td>14</td>
</tr>
<tr>
<td>16. The concept of the magnetic device</td>
<td>15</td>
</tr>
<tr>
<td>17. The concept of how the magnetic device works</td>
<td>15</td>
</tr>
<tr>
<td>18. Walking cycle</td>
<td>16</td>
</tr>
<tr>
<td>19. Testing the model</td>
<td>17</td>
</tr>
<tr>
<td>20. The second model</td>
<td>18</td>
</tr>
</tbody>
</table>
21. The magnet on the second model ........................................ 18
22. The design of the magnetic device ...................................... 19
23. How the magnetic device works ......................................... 20
24. The double size model of the magnetic device ..................... 21
25. The drawing of the switch mechanism .................................. 22
26. The switch mechanism .................................................... 22
27. The working model of the magnet device ............................ 22
28. How the switch works .................................................... 23
29. The components of the walking aid .................................... 24
30. Electronic sphygmomanometer 1 ........................................ 25
31. Electronic sphygmomanometer 2 ........................................ 25
32. Walker for elderly people ................................................ 25
33. Wearable walking aid ..................................................... 25
34. The computer renderings of the walking aid ......................... 26
35. The dimensions of the walking aid needed to be adjustable .... 27
36. The position of walking aid on the body .............................. 28
37. The magnetic device ..................................................... 29
38. The position of pivot point related to hip joint ..................... 29
39. The back support ........................................................ 30
40. The thigh support bar and the thigh brace .......................... 30
41. The full-scale model ..................................................... 31
42. The side view of the walking aid on the model ...................... 31
43. The 45 degree front view of the walking aid on the model ........ 31
<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>The 45 degree rear view of the walking aid on the model</td>
</tr>
<tr>
<td>45</td>
<td>The power button on the side panel</td>
</tr>
<tr>
<td>46</td>
<td>The battery life panel</td>
</tr>
<tr>
<td>47</td>
<td>The battery life panel on the side panel</td>
</tr>
<tr>
<td>48</td>
<td>The battery life panel separated from the side panel</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Body measurement of male population</td>
<td>27</td>
</tr>
<tr>
<td>2. Body measurement of female population</td>
<td>28</td>
</tr>
<tr>
<td>3. The size chart of the magnetic device</td>
<td>29</td>
</tr>
<tr>
<td>4. The size chart of the back support</td>
<td>30</td>
</tr>
</tbody>
</table>
Chapter 1

INTRODUCTION

The increase of elderly population will be a serious problem in the future. Today, there are 35 million Americans aged 65 and older. By the year 2020, there will be 50 million older Americans, and 70 million by 2030. At that time, almost one in every four Americans will be over the age of 65. Not only in the United States, but also in Japan, one fourth of the population will be aged 65 or older in 2015. By the year 2020, close to 50% of Europe’s adult population will be aged 50 or over. These statistics reveal one of the most profound social changes of our time: Elderly people will not be the minority in the future. More and more equipment will be needed and designed to help them in their daily lives.

![Graph showing the number of elderly people over age 65 in the United States (in millions)](image)

Fig. 1. Number of elderly people over age 65 in the United States (in millions)

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Although aging is unavoidable, it can be slowed by proper and regular exercise. Walking is one of the most appropriate activities for senior citizens. It is inexpensive, simple, and almost anybody can do it. Therefore, keeping up the walking abilities of the elderly is beneficial for them. The walking aids available now, such as walkers and crutches, are all designed for people who already have walking problems, such as an injury or arthritis. The way of using this equipment is to rely on the strength of arms to support the users'
bodies. This is not easily performed by elderly people. They start to lose the strength in their arms because of the natural process of aging. Besides, for those who just started to have slight walking problems, such as the weakness of muscles, these walking aids are not suitable for them. There should be some equipment designed for them to keep walking and using the muscles of their legs.

For this thesis project, I will design a wearable walking aid for elderly people in order to help them walk easily and maintain their independence and mobility. This walking aid will also be a piece of exercise equipment made to help elderly people gain more exercise and have more fun walking. In addition, by wearing it, people can keep their self-esteem and have more confidence compared to using canes or walkers. This walking aid is designed for them to maintain their health in both physical and psychological ways.

Here is the brief description of this thesis project:

**Target:** Elderly people who start to have walking problems due to the weakness of their muscles caused by the natural process of aging.

**Problem:** For these elderly people, they need some equipment to help them to walk. By promoting exercise from walking, they can maintain their independence and health. The current walking-aid products, such as walkers, crutches, and canes cannot help people to gain exercise from walking. They are all designed for people who have serious walking problems.

**Solution:** A product designed for elderly people to help them not only walk more easily but also maintain their health from exercise -- Wearable walking aid.
For elderly people, a common problem is the weakness of muscles caused by the natural process of aging. Muscles provide the force and strength to move the body. Coordination, although directed by the brain, is affected by changes in the muscles and joints. Changes in the posture and gait, weakness, and slowed movement are caused by changes in the muscles, joints, and bones. This problem also causes other problems: People start to have less exercise when their muscles start to get weak. Consequently, when they have less exercise, other problems, such as heart disease, start to happen.

According to the Report of HHS Today from the Department of Health and Human Services on June 21, 2002:

Few older Americans achieve the minimum recommended 30 or more minutes of physical activity on five or more days a week. About 28 percent to 34 percent of adults aged from 65 to 74 and 35 percent to 44 percent of adults age 75 are inactive, meaning they report no leisure-time moderate activity. Lack of physical activity and poor diets are the major causes of an epidemic of obesity that is affecting the elderly as well as younger populations.  

From the research, the biggest health problem of elderly people is lack of exercise, and regular exercise, such as walking, can help them to prevent a lot of diseases, such as cancer, heart disease, and diabetes. Also, exercise is one of the best ways to slow or prevent problems with the muscles, joints, and bones. "The importance of physical activity to older Americans can't be stressed too much," said HHS Assistant Secretary for

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4
Aging Josefina G. Carbonell. "An active lifestyle is achievable and it helps people live independently longer."\(^3\)

From the HHS report, walking is the most recommended exercise for elderly people. Dr. Michael Pratt, the acting chief for the Physical Activity and Health Branch in the Division of Nutrition and Physical Activity at the Center for Disease Control and Prevention in Atlanta (CDC), says "Walking is a tremendously good activity for senior citizens. It's cheap, it's simple, almost anybody can do it, and walking has a multitude of health benefits for everyone. It helps seniors and has very real benefits for maintaining mobility and independence."\(^4\)

Walking is wonderful exercise for anybody, but it's particularly good for the elderly. As a weight-bearing exercise, it helps build bone mass, which protects against fractures. Walking is also good for the heart.

According to Emily Smith, the benefits from regular physical activity such as walking include:

- Help in preserving our mental abilities
- Reduced risk of dying prematurely
- Decreased risk of dying from heart disease
- Decreased risk of developing colon cancer
- Reduced risk of developing high blood pressure

\(^3\) Simpson.

· Help in reducing blood pressure in people who already have high blood pressure
· Help in controlling weight
· Decreased risk of developing diabetes
· Lower risk of developing hypertension
· Increased muscle strength, flexibility and sense of balance, all of which reduce the risk of falls\(^5\)
Chapter 3

THE RESEARCH OF CURRENT WALKING AIDS

From the last chapter, we know the ability to walk is important for maintaining health and independence in the elderly population. Is there any equipment currently available to help them keep walking and get exercise from walking?

The current walking-aid products, such as canes, crutches, or walkers are basically designed to use the arm strength to help people walk. The current products are used to help users keep either their balance or body mobility. People start to use walking aids after they already have really serious problems walking, such as osteoarthritis, or other joint and bone problems.

The current walking-aid products:

**Canes:**
A cane typically is used when only one upper extremity is required for balance or bearing weight.

Canes widen a person's base of support, thereby providing increased balance. While canes have traditionally been used only for balance and not weight bearing, modified designs such as quad, and walk canes permit various degrees of weight bearing through the cane. The gait pattern of a person using a cane usually involves placing the cane in the opposite hand from the leg with the most severe deficit. The cane is then advanced with the opposite (deficient) leg, consistent with normal gait.6

Crutches:

![Fig. 7. Forearm crutch](image1)
![Fig. 8. Axillary crutch](image2)

Crutches are typically used to provide weight-bearing ambulation support to persons with temporarily restricted ambulatory status.

Crutches increase the base of support, thereby improving lateral stability. In contrast to canes, crutches can be used for full weight bearing. Because of the wide base needed for ambulation and the considerable strength needed to use crutches, they are often cumbersome and difficult to use.7

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7 Van Hook, 1721.
Walkers:

A walker is the most stable walking aid, but it requires a slower, controlled gait pattern because users must be able to pick the walker completely off the ground and place it forward before stepping forward.

Walkers improve balance by increasing the patient's base of support, enhancing lateral stability, and supporting the patient's weight. Despite the enhanced support and utility for weight bearing, walkers also have disadvantages. These include difficulty maneuvering the device through doorways and congested areas, reduction in normal arm swing, and poor posture with abnormal flexion of the back while walking. In general, walkers should not be used on stairs.\(^8\)

The current walking aids use the strength of the arms to keep either the balance or body mobility of elderly people. This causes the elderly to have some difficulties using them, and perhaps don’t walk as much as they should. When they walk less, the ability to walk diminishes. There should be some device designed to use some kind of support to help them walk easily and keep using leg muscles to gain exercise.

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\(^8\) Van Hook, 1722.
Chapter 4

CONCEPT DEVELOPMENT AND THE DESIGN PROCESS

ORIGINAL IDEA AND CONCEPT

The original concept of this project was inspired by the robot designed by Honda Motor. This robot can simulate the walking posture of human. The technology might be able to be applied to a walking aid. The idea is to put some mechanism such as motors on a walking aid which is worn on a person's body, and the force from motors can give users' legs support and allow them to walk more easily. By wearing this walking aid instead of holding it like current products, such as canes, or walkers, people can feel more comfortable, more confident, and more independent.

Fig. 12. The robot designed by Honda Motor

The concept of the walking aid is to save users' energy, but people still need to use their own muscles and will be able to gain exercise from walking. It is similar to riding a bicycle. By using this equipment, people can walk longer so they will have more
confidence to go out and remain independent. People also can be more relaxed so they will have more fun walking, and at the same time keep themselves healthy.

Fig. 13. Sketches of the original concept

From the sketches, the original concept is to have users wear some kind of mechanical structures on the side of their legs. Motors or other mechanism work in the joint part to move the bars connected to their legs and support them when users are walking. The amount of support is controlled so users can save some energy but still use their own muscles.
HOW TO SUPPORT?

To support the legs, some kind of mechanism is needed in this walking aid. The weight of the mechanism has to be as light as possible because this walking aid will be worn. Also, this support should be able to be adjusted easily and controlled easily by the movement of the legs.

The first idea was to use motors, but there are a lot of problems using them. The weight of motors is too great, and their strength cannot be easily adjusted. It is also very hard to control the motors to simulate the walking postures of human. The biggest problem is that the use of motors will make people walk unnaturally because motors cannot react immediately. Thus, the idea of using motors was rejected. Another solution was needed.

The second idea was to use springs. Springs have some advantages; they are light-weight, can react immediately, and can help people walk more naturally than using motors. The problem with springs is they have to be compressed and released in a very short period, which is difficult to do. Besides, the best way to compress springs is by using people’s body weight without using other mechanisms. However, when people use their bodies or movements to compress the springs, they also use their energy at the same time. The goal of this product is to conserve people’s energy when they are walking, so the use of springs is not a good idea.
THE SOLUTION: ELECTROMAGNETS

After doing research, I found two types of energy are mentioned to be very important in the future. One is solar power, and the other is magnetic force. The characteristics of magnets might be very suitable for this product.

Electromagnets can be easily found in everyday life. They are used in products such as motors, speakers, and magnetic locks. The basic idea behind an electromagnet is extremely simple: By running electric current through a loop of wire, you can create a magnetic field. Electromagnets can easily be controlled by current and can provide strong force. A small one-inch diameter and one-inch long electromagnet can easily hold more than fifty pounds.

A good example is Maglevs (magnetically levitated trains). The concept of maglev transportation was developed more than a century ago. In 2002, the first commercial maglev train made its test debut in Shanghai, China, using the train developed by German company Transrapid International. Nowadays, Germany and Japan are both developing maglev train technology, and are currently testing prototypes of their trains. The principal of a maglev train is that it floats on a magnetic field and is propelled by a linear induction motor. They follow guidance tracks with magnets.9

A maglev train floats about 10mm above the guide-way on a magnetic field. It is propelled by changing magnetic fields on the guide-way itself rather than an onboard engine. The same poles of magnets repel each other and the opposite poles of magnets attract each other. Once the train is pulled into the next section of the guide-way, the magnetism switches so that the train is pulled again.¹⁰

¹⁰ Keating.
The idea of using electromagnets is to use the force from repulsion of two magnets to support people’s legs. Please see figure 16. Two magnets will be fixed at specific angles. Another magnet will be set on a bar, which connects to the leg and can be moved on a track.

![Fig. 16. The concept of the magnetic device](image)

Please see figure 17. When the bar moves with the leg, the magnet on the bar will move close to the angle of the magnet which is fixed. Once these two magnets are at the same angles, a switch will close and turn on these two electromagnets. The contact sides of these two magnets are set to same poles, so they repel each other. The repulsion will push the bar which connects the leg and the force supports the leg when walking. In order to design this magnetic device, a study of walking postures was needed.

![Fig. 17. The concept of how the magnetic device works](image)
WALKING CYCLE AND POSTURES

To develop the concept of this product, a study of walking cycle and postures was necessary. Some information was found in motion analysis, which is the study of human movement. When motion analysis is applied to human walking, the study is known as gait analysis. Additional information was found in the animation field. In order to simulate human’s walking postures, some research has been done by animation technologists, who put motion sensors, known as captures, on people’s bodies and use computer technology to obtain a detailed report of how different parts of the body interact when they are in motion.

Figure 18 shows the way people walk.

The human walking step is composed of two different phases. The first phase is the swing phase or single support phase when one foot is on the ground while the other swings. This phase begins with the moment of liftoff (Figure 2, 5) and ends with the collision of the swing foot with the ground (Figure 3, 6). This phase makes up the majority (80–90%) of the duration of the walking step in human walking. The second phase is called the double support phase (Figure 1, 4) as both feet are on the

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ground while the body is moving forward. This phase usually makes up only a small part (10–20%) of the human walking step.¹²

Immediately at the beginning of the swing phase is the moment of liftoff. Here, the foot is just propelling the body forward so that the leg loses contact with the ground. It is at this moment of liftoff that this walking aid is going to give the leg support.

To understand the walking cycle and test the concept, a test model was made. It is made of wood bars and has two pivots on the hip joint and knee joint. This model has two functions. First, this model can test the concept of this product to see if people can walk naturally and freely while wearing it. Secondly, from this test model, the change of the angle between the thigh and the body when people walk can be measured. This is very important to find out the angles of the two support points because these two angles are where the electromagnets will be located. The test results seem to indicate that there is no problem for people to walk with it, but this product has to fit the shape of the human body to move more smoothly.

Fig. 19. Testing the model

To verify the idea more, a second test model was made. It has a structure similar to the first one, with the addition of regular magnets on it. The magnets are arranged with the same poles on the side that face each other, so they repel each other when they converge. The regular magnets used on this model provide twenty pounds of repulsion. When wearing this test model, one can feel the force from the repulsion of the magnets. It proves that the idea of using magnets is possible, but the test model still cannot work properly because the magnets cannot be turned off. The electromagnets will only be turned on at the moment of the supporting point, because it is the only moment which will give legs support from the repulsion of two magnets. Figure 20 and 21 show the second model with the magnets.

THE MAGNETIC DEVICE

After doing the research on walking postures and making two test models, the basic concept of the magnet device was formed. It was to locate electromagnets at the specific angles of the support point, and the repulsion from two magnets will give support when
legs move through these angles. From the research of the walking cycle, the angle of the leg to the centerline of the body profile ranges from twelve degrees backward to thirty degrees forward (Fig. 22). This data comes from the measurement of the general adult male population. Unfortunately, data on the gait of elderly male and female populations does not exist. The position of the magnets should be set smaller than the angle of leg movement to let the legs pass the magnets while walking. Also, because elderly people usually have smaller steps, the angles of leg movement will be smaller than that of average people. To test the model, I decide to set the angles of the magnets at six degrees backward and twenty degrees forward. These angles will be the original setting of the magnet device and should be adjustable to fit different people.

Fig. 22. The design of the magnetic device

Figure 23 shows that there is one electromagnet on a supporting bar, which connects to the thigh of one leg and moves with the leg. Two electromagnets will be set at the angle of the support points. When the bar moves to the angle of one support point, a switch will close, and the electromagnet on the bar and the electromagnet on the support point will both be turned on and will repel each other. The repulsion will be the force to push the support bar and help the leg move.

To show and test the design of the magnetic device, a model was made. It is double size of the real device and the angles of the magnets are set at six degrees and twenty degrees. This model shows the dimension of the magnetic device and the position of electromagnets. However, the magnets on this model are permanent magnets. They
cannot be turned on and off, and the device still cannot work as intended. Figure 24 shows the model and the angles of magnets.

![Fig. 24. The double-size model of the magnetic device](image)

A working model of the magnetic device was then made. To allow this model to work properly, there are two switches set on the angles of supporting point -- the angles where the electromagnets are positioned. From the preceding, you can see the electromagnets will only be turned on at the specific angles, and also only work when the leg passes in one direction. When the leg passes from the opposite direction, the electromagnet will not work. Thus, these two switches have to be designed to work only when they are hit in one direction and not work in the other. For the actual product, it is easy to have electro-switches perform this function. For the model, a mechanism was made to do the same operation.

The switch mechanism on this model used a wheel connected with the bar, which moves
with user’s leg. When the bar moves with the leg, a piece of semicircular sheet metal which connects the wheel with the same pivot will rotate with the wheel. This metal piece will hit the switch when it rotates and touches the surface. When the bar goes back to the opposite direction, the metal piece will pass the switch.

![Wheel](image)

**Fig. 25. The drawing of the switch mechanism**

Figure 26 and 27 show the switch mechanism and the working model of the magnet device.

![Switch](image)

**Fig. 26. The switch mechanism**

**Fig. 27. The working model of the magnetic device**
Figure 28 shows how the switch works.

1. The support bar moves to the angle of support point. The metal piece is going to hit the switch.

2. The metal piece is hitting the switch.

3. Two electromagnets are turned on.

4. Two electromagnets repel each other. The support bar is pushed by the strength from repulsion.

Fig. 28. How the switch works
THE COMPONENTS AND APPEARANCE OF THE WALKING AID

When the concept of the magnet device was developing, the design of the walking aid also developed at the same time. To wear it, there should be a belt, that is flexible to fit on the body. However, a belt cannot hold the body very well, and the magnetic device might shift when it operates. To prevent that, a wide back support made of soft material was used in place of the belt in the back. The belt will be used only in the front of the body. There is a side panel to connect the back support and the magnet device. This side panel also is designed to let the position of the magnetic device be adjustable to help the walking aid fit the individual user. Figure 29 shows the components of the walking aid.

Fig. 29. The components of the walking aid
The appearance of this product was kept clean and simple. The goal is to let it be easily accepted by the users -- elderly people. Some current products for the elderly were used for reference in the appearance of the design. Subsequently, the walking aid was given a smooth, succinct look, and the idea was to give an image of exercise equipment. The color choice of this product is intended to keep it unobvious. Dark blue and light blue are two main colors used. Dark blue gives the product a steady feeling, and light blue makes it look not too heavy. The yellow circle on the magnet device marks the position of the pivot, and also gives it a sporty feeling. Figure 30, 31, and 32 show the current products for elderly people, and figure 33 shows the wearable walking aid.
Figure 34 shows the computer renderings of the walking aid.

Fig. 34. The computer renderings of the walking aid
BODY MEASUREMENTS AND HUMAN FACTORS

Because this product is designed to be worn on the body, it is vital to use accurate anthropometric data in the design process. To fit properly, the dimensions of the walking aid for the following have to be adjustable:

- Waist to hip joint
- Hip joint to knee joint
- Waist

![Diagram showing dimensions of walking aid](image)

Fig. 35. The dimensions of the walking aid needed to be adjustable

Table 1 and 2 show the data of body measurement. By using the data, the size of each component of the walking aid can be determined.

<table>
<thead>
<tr>
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<th>99 Percentile Man</th>
<th>50 Percentile Man</th>
<th>1 Percentile Man</th>
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<tbody>
<tr>
<td>Waist to Hip Joint</td>
<td>8&quot;, 203mm</td>
<td>6.1&quot;, 155mm</td>
<td>4.6&quot;, 117mm</td>
</tr>
<tr>
<td>Hip Joint to Knee</td>
<td>18.4&quot;, 467mm</td>
<td>16.7&quot;, 424mm</td>
<td>15.2&quot;, 386mm</td>
</tr>
<tr>
<td>Abdomen (thickness)</td>
<td>13.7&quot;, 349mm</td>
<td>10.5&quot;, 267mm</td>
<td>7.9&quot;, 201mm</td>
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Table 1. Body measurement of male population

### HOW TO FIT ON THE BODY?

Because of the variety of human body sizes, it is difficult to have “one size fits all.” The way to fit this wearable walking aid on different users is to have different size components. A physical therapist can choose the correct size of the components for users and assemble them together to fit users perfectly. Figure 36 shows the position when the walking aid is worn on the body.
As mentioned before, three parts of the walking aid have to be adjustable. The following shows the components related to these three parts.

The position and the length of the magnet device: waist to hip joint

![Fig. 37. The magnetic device](image)

![Table 3. The size chart of the magnetic device](image)

The pivot of the magnetic device and the hip joint of the user have to be on the same horizontal line. There are four different sizes of the magnet device, and the position of the magnet device can be adjusted on the side panel so the pivot can match the position of the hip joint. For example, the small size of the magnet device is 5 inches long and it can be adjusted on the side panel to fit the length of waist to hip joint from 4 to 6 inches.

![Fig. 38. The position of pivot point related to hip joint](image)
The back support and the front belt -- waist:

Fig. 39. The back support

<table>
<thead>
<tr>
<th>Size</th>
<th>Waist</th>
<th>Fitting range</th>
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</thead>
<tbody>
<tr>
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<td>24”</td>
<td>24”~28”</td>
</tr>
<tr>
<td>S</td>
<td>28”</td>
<td>28”~32”</td>
</tr>
<tr>
<td>M</td>
<td>32”</td>
<td>32”~36”</td>
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<td>36”</td>
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</tr>
<tr>
<td>XL</td>
<td>40”</td>
<td>40”~44”</td>
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</table>

Table 4. The size chart of the back support

The back support and the belt have five different sizes from extra-small to extra-large. They can fit people from a 24-inch waist to a 44-inch one. For example, the medium size is 32 inches and can be adjusted to fit on users from 32 inches to 36 inches of waist.

The length of the supporting bar -- hip joint to knee joint:

Fig. 40. The thigh support bar and the thigh brace

The length of the supporting bar is related to the length from hip joint to knee joint of users, and the form of the bar is designed to match the thigh shape. Also, the brace has to match the size of users’ thighs. These two components will have variable sizes available for users.
Figure 41 ~ 44 show the full-scale model and how it fits on the body.

Fig. 41. The full-scale model

Fig. 42. The side view of the walking aid on the model

Fig. 43. The 45 degree front view of the walking aid on the model

Fig. 44. The 45 degree rear view of the walking aid on the model
THE CONTROL

There is a simple control for this walking aid. The control will be a power button to easily turn the walking aid on and off, and a display panel to show the life of the battery. The control will be easy to hold, and buttons are located singly and separately, so they are much easier for the elderly to see and press. The battery life panel can be separated from the side panel to be read easily, and, with a connecting cable, it won’t get lost. The means of indicating the life of the battery on the panel is a symbol of the battery. It can be easily understood by how many LCD segments are turned on.

Fig. 45. The power button on the side panel
Fig. 46. The battery life panel
Fig. 47. The battery life panel on the side panel
Fig. 48. The battery life panel separated from the side panel
ABOUT THE WALKING AID

Where to get wearable walking aid?
The elderly can visit a physical therapist who will check their walking problems. If their problem is due to muscle weakness and not to other serious joint or bone problems, the therapist may suggest they use this walking aid, and will adjust and assemble it for them.

What does the physical therapist do to adjust the walking aid?
If the physical therapist suggests people use this walking aid, he or she will do the following to fit it perfectly.

- Measure the user’s body, choose the size of parts, and assemble it
- Do a gait analysis, adjust the magnet angle
- Test muscle strength, adjust the strength of magnet force

What can people do with the walking aid?
For elderly people who live in an urban area where most people use a mass transportation system, this walking aid can be used to maintain their mobility. By using it, elderly people can go shopping, visit friends, and also keep exercising at the same time. For those who live in the suburban area of a city, where people usually drive, the walking aid can simply be used as exercise equipment. The elderly can easily use them in the park or even just in the neighborhood. By walking longer and more easily, they can have more fun walking, and this exercise will be truly beneficial to their health.
Chapter 5

CONCLUSION

The target users of this product are elderly people. For many reasons, safety is the most important issue when designing this product. It is necessary to have accurate measurements and know how much support is suitable for each user. From the test of models, for people around 120 ~ 130 pounds, the support around 40 pounds will be needed. However, without professional equipment and technical support, it is difficult to determine accurate numbers. For production products, more professional tests need to be done. Also, many safety tests on users need to be completed before this product can be released on the market.

Besides the safety issue, another major concern is the weight and size of this product. In the future, some new technologies will help to improve this product. Currently, the walking aid uses Lithium-ion battery that is the heaviest part of it. The weight of the walking aid estimated from the model is around 6 pounds, and the battery is around 2 pounds. The walking aid will be much lighter as new batteries are invented which are lighter and have longer life. Another new technology, which might be able to be applied on this product, is the super conduction magnet, a new kind of electromagnet made by super contact materials. It can produce much stronger magnets which use less energy, so the weight and the size of this product can be much smaller.

From the design process of this walking aid, I have been challenged when dealing with
the mechanism problems. This has been a very valuable experience and will help me in my future career. A designer has to be concerned with many different aspects of a product, and thorough research is very important and helpful before starting the design process. From this thesis project, I am very glad that I had the chance to focus on the needs of the elderly. There should be more designers who care about their needs because they will not be the minority in the future.


