POLITECNICO
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Multifunctional crutch

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Abstract

Design of multifunctional forearm crutch. By observing the daily scenes of crutch users, analysis the real needs of users. Redesigned forearm crutches. With the help of the spring system, the user can easily stand up from the chair, while maintaining the user's balance. The upper arm structure can be disassembled freely. The user's hands can move freely without leaving the forearm crutch.

Introduction

Currently, the market for walkers is growing rapidly. Given the large consumer market, the aging population due to the increase in sprains and sports injuries, more attention should be paid to the improvement of crutches.Although the innovation of industrial products is very rapid, design has not played a decisive role in the types and innovation of crutches, and there has been no large-scale innovation in more than ten years. This topic has a wide market space, and the design of a new multi-functional walking stick has important practical and social significance for people who suffer from sports injuries and users of walking stick with balance problems.

Starting from the research on the development history of crutches, this paper investigated the age distribution of crutches users, main diseases and major manufacturers, and then analyzed the function and structure of various crutches on the market. From the use scenarios, we found that crutches users often had difficulty getting up from the chair. When using the forearm crutch, it is impossible to move the arm freely, so we try to improve the structure and components of the forearm crutch through a large number of schemes, and also improve the material.

Focusing on the various problems encountered by users of crutches in real scenes, this paper redesigned the forearm crutches to meet users' physiological and psychological needs, so as to meet their needs when getting up from the chair and taking things at any time. In addition, the design of multifunctional walking stick is described and studied in detail.

Indice

1. Historical Development

1.1 The appearance of crutches

Back in history, crutches have been around for centuries. Engravings of figures apparently supported by a cane-shaped object have been found on Egyptian tombs dating back to 2830 BC, a shape very similar to that of a modern walking stick.

In popular Literature in Europe in the early 19th century, many fictional characters walked with crutches. Such is the case with Tiny Tim in Dickens's A Christmas Carol.

In addition to crutches, walkers developed other forms. The British Museum's first-century terracotta figures show a walker supported by some kind of frame.

In the case of Hieronymus Bosch, the Dutch artist, among his religious stories and some of his works, there is a painting showing that walking frames had been around for hundreds of years.[1]

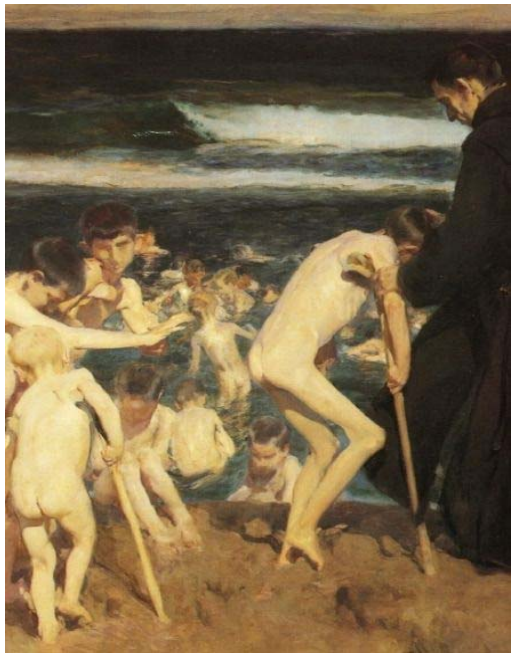


Figure 1-*1899-Joaquín Sorolla's painting Sad Inheritance shows disabled children bathing at the sea in Valencia. The polio epidemic that struck some years earlier in Valencia is present, possibly represented for the first time in the history of painting, through the image of two affected children with crutches.[* Source *: https://www.pinterest.it/pin/686165693198274254/]*

1 The Evolution of Crutches - From Ancient Egypt to Bill Clinton Sally Madeley-Carr, OT https://www. essentialaid s.com/ blog/ evolution-crutches-ancient-egypt-bill-clinton.html

1.2 History of Forearm Crutch

French engineer Emile Schlicke designed and produced the first pair of Forearm Crutches, which were mass-produced in New England in the United States in 1917. In this design, for the first time, there is a metal bracelet that wraps around the user's arm, with a sloping top.

Soon, the first World War broke out, and many soldiers' demand for walking AIDS increased wildly, so its sales increased greatly. Many soldiers injured in the battlefield slowly recovered through this kind of walking AIDS.

Anders R Lofstrand Jr was the person who later made technical advances in crutch design. His family, Swedish immigrants to the United States, owned a successful salon and restaurant business. In World War II, the company won several lucrative government contracts and filed a patent application for an adjustable version of Schlick's original design in 1945. Lofstrand's most important modification was to make the length of the crutch's forearm and lower axis adjustable, allowing them to be adjusted to fit the individual user's frame.

In this case, the patent was granted just 10 years later, and Lofstrand died of cancer two months later at the age of 42. Still, in many parts of North America, the Forearm Crutch is known as the Lofstrand. They may also be called "Canadian" crutches, possibly because of the popularity of the design in Canada.

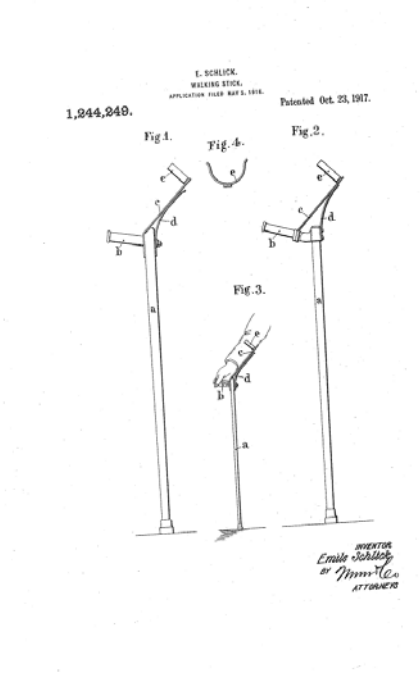


Figure 2-Emile Schlick's original design. [Source .: http://www.google.com/patents/US1244249]

1.3 History of axillary crutch

In the 14th century, religious scenes also appeared on the embroidered clothes of a deacon, and a walking frame with wheels was used.

The early supporting crutches should be a piece of wood of appropriate length, put it under the arm, and this piece of wood provides moving support when people walk. It can save people effort and rest, which has slowly evolved into a "T-shaped" crutch, with a horizontal beam installed on the top of a vertical wooden rod.

Later, gradually, those early T-shaped crutches shifted to v-shaped designs. The hardwood at the top is slowly splitting. It separates horizontally on either side. The V-shaped crutches gradually became the underarm support section, and at the bottom of the fork, a handheld section was designed, with the top section supported under the armpit. Although it doesn't have any padding to reduce the friction in the underarm area, it does reduce the vertical pressure on the user's legs, channeling the exertion of walking to the upper body.

1.4 History of walking stick

Shepherds and travelers like to use stick of can (can). These things can fight thieves and robbers, and can be used to make animals move forward orderly. With the development of time, stick of can has new symbols, representing power and power. Many rulers and cultural celebrities will bring a stick of can around in different forms.2

Almost all rulers of Egypt will carry stick of cane, and there will be decorative knobs of various shapes on the top, which represents longevity.

The gods of ancient Greece often carried scepters in their hands in scenes. They are made of very valuable materials, ivory, ebony, and other rare woods. It also represents a person's wealth and social status. A scepter in the right hand symbolizes royalty, and a scepter in the left represents justice.

The church also uses this symbol, the bishop's Stick of Cane, which has a little twist, a hook.

Stick of Cane became part of men's everyday dress after the 1600s. During this period new rules of etiquette were developed. A breach of this code of conduct is considered a breach of courtesy. In 1702, Londoners had to hold a license to carry stick of Cane or Stick of Cane. An example of the Stick of Cane license is: You are hereby required to permit the person carrying stick of Cane to pass and re-pass through the streets of London, or anywhere within ten miles of it, without theft or harassment: Provided he doesn't carry it around with him waving it under his arm or hanging it on a button3. In the late 17th century, Puritans and fashionable men began to carry stick of cane with them, and the design of stick of cane went to a new level. Stick of cane adopted a variety of materials, including natural and man-made materials. After carving and decoration, some hidden compartments were added inside to place daily necessities. By 1931, Gradually, stick of can became a symbol of the visually impaired.

After World War II, Dr. Richard Hoover invented the stick of cane to help retired blind soldiers restore a normal lifestyle. The use of stick of can has also entered a new era[4].

2 Lester and Oerke Accessories of Dress, Peoria, IL -The Manual Arts Press https://fashionablecanes.com/pages/ about-canes
3 Lester and Oerke Accessories of Dress, Peoria, IL -The Manual Arts Press https://fashionablecanes.com/pages/ about-canes
4 History of Canes https://fashionablecanes.com/pages/about-canes

1.5 Famous crutch manufact urer

Company Information: List Of Top Manufacturers/ Key Players In Canes and Crutches Market Insights Report Are:

Ossenberg GmbH

The company is one of the leading manufacturers of forearm crutch, stick of can and orthopedic AIDS in Germany. Ossenberg GmbH is a modern, success oriented company with a tradition[5].

It has worked tirelessly with top R & D teams from many countries, created many innovative designs and won more than 100 patients. The goal is to provide the best mobile solutions for people from all walks of life. Today, karma is an international brand, sold in more than 40 countries around the world.

Passion and compassion are the hallmarks of karma. Karma is committed to improving the lives of the elderly and the disabled and helping them live the most fulfilling lives[6].

- C.T.M. Homecare Product, Inc.

The Australian Centre for Independent Living (ILCA) is a collective network of ILC members from all Australian states.

5 https://shop.ossenberg.com/en/detailbeschreibung-smart-stick/
6 Figure. https://karmahealthcare.com/about-karma-the-beginning/

2. Users

2.1 Age distribution of crutches

In Europe, crutches are used across a wide range of ages. According to the report, about 40 percent of healthy respondents have used crutches for various reasons, and many have used them multiple times. Crutches range in age from 5 to 85, covering almost all ages of life. It was always thought that middle-aged people might be the main users of crutches. But this conclusion has been revised as more data have been available, and surprisingly, crutches are most commonly used among teenagers, when humans are more active and the body is not fully mature, leading to more fragile bones. The second largest group of crutches users is older than 65, mainly due to osteoporosis. In the data, we can see that people between 15 and 30 years old account for the largest proportion, followed by teenagers under 15 years old, because the bones of teenagers are in the growth stage, they are often likely to have serious sports injuries. Crutches are highly mobile in the hospital service ecosystem because most sports injuries are temporary (mainly temporary sports injuries such as fractures and ankle sprains). Many patients with crutches recover within six months.

2.2 Frequency of use by different age groups

Through comparative analysis, young males aged 15-24 are more likely to have sports-related injuries, while females aged 5-14 are more likely to have the highest risk of sports-related injuries. The next highest risk range is between the ages of 25 and 39, with men's injury rates decreasing over time. In contrast, the risk of sports injuries increased for women over 55[7].

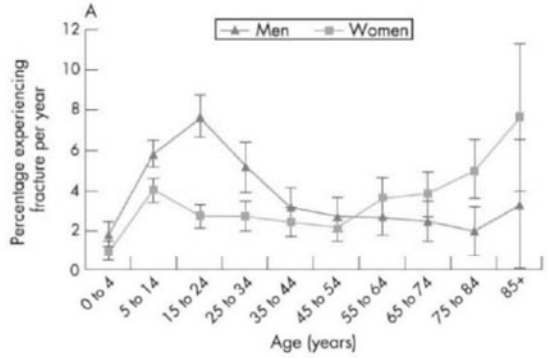


Figure.14 *The age group distribution of ankle injury*
Source: Donaldson et al., 2008

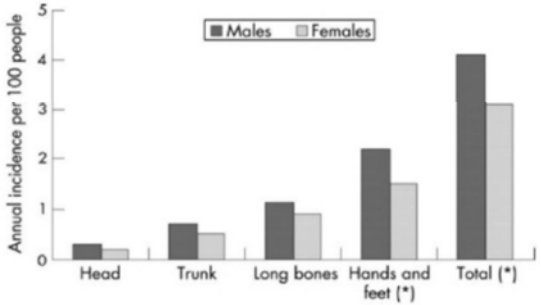


Figure.15 *The distribution of different fracture types*
Source: Donaldson et al., 2008

Figure 3-

7 Bauer, D.M., Finch, D.C., McGough, K.P., Benson, C.J., et al. (1991). A comparative Analysis of Several Crutch-Length-Estimation Techiques. PHYS TER. 71(4), 294-300 Bridgman, S.A., Clement, D., Downing, A., et al. (2003). population based epidemiology of ankle sprains attending accident and emergency units in the West Midlands of England, and a survey of UK practice for severe ankle sprains. Emerg. Med. . 20, 508-510

2.3 Main disease

Among the major diseases of using crutches, except for a few permanent diseases, most of the injuries are temporary and can be recovered within six months, and the mainstream patients fall into this category. Of these, the most common temporary lower limb injuries are sprains and fractures[8].

2.3.1 Sprain

Sprains are the most common temporary sports injuries. The most common type of sprain occurs when a person's ligaments are stretched with excessive force and torn, affecting the muscles and ligaments. In Europe, about 5600 people will suffer ligament injury every day, and the incidence of ankle sprain is 0.052%. In the population, teenagers are the main group of ankle injuries, and the incidence of ankle injuries will gradually decrease with the increase of age[9].

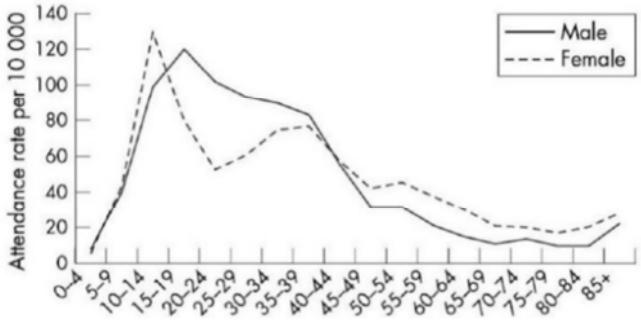


Figure 4- The age group distribution of ankle injury Source: Bridgman et al, 2003

The main cause of ankle sprains is various sports that teenagers enjoy, such as football, basketball and volleyball.

Young men, in particular, are more enthusiastic about participating in such sports. Ankle sprains in football account for 29% of all lower limb injuries. Forty-five percent of basketball injuries were ankle-related, and 31 percent of football injuries were ankle-related[10].

Common symptoms include tenderness, swelling, inflammation, and bruising. Crutches are commonly used in ankle patients. Because the legs can no longer support the weight of the body, although the sprain can slowly heal through self-care. But you still need to be more careful, and you need to rely on crutches for at least 6-8 weeks to get through

8 Garrick, J. M. (1977). The Frequency of Injury, Mechanism of Injury, and Epidemiology of Ankle Sprains. Am. J. Sports Med. 5, 241-242
9 Geber, J.p., Williams, G.N., Scoville, C., et al (19). Persistent disaility associated with ankle sprains: a prospective examination of an athletic population. Foot ankle international. 19, 653-660.
10 Hasselman, C.T., Vogt, M.T., Stone, K.L, et al (2003). Foot and ankle fractures it elderly white women: incidence and risk factors. The Journal of Bone and Joint

the recovery period[11].

2.3.2 Fracture

In contrast, fracture injuries are more serious. Continuous fractures are often caused by sudden strong force or pressure on the bone, and their pathologic features are very complex, which can cause a variety of concurrent injuries[12].

Donaldson et al. (2008) conducted a study to assess the annual and lifetime prevalence of fractures in the United Kingdom. The incidence of fractures in recent years has been significantly higher than in the past, reaching 3.6% in 2008. Caucasians are more likely to break bones than other ethnic groups, and men are significantly more likely to break bones than women. According to their survey, young men (15-24 years old), girls (5-14 years old), middle-aged and elderly women are considered to be the main population at highest risk of fracture. In addition, the feet and hands were identified as the most common sites of fracture injuries. Depression or accidents due to their motivation. As people age, their bones weaken and the incidence of fractures increases. In addition to external forces, other factors such as disease, infection, tumor or cyst can cause a fracture. These fractures are called pathological fractures and are most common in older people. A study by Hasselman et al. (2003) also showed that although the incidence of ankle and foot fractures in older women was quite similar, the causes were quite different. Ankle fracture is mainly caused by slip and other accidents, and foot fracture is typical osteoporotic fracture. As with sprains, patients with lower limb fractures may need to use crutches to help them get out of bed during treatment. The recovery time for a fracture depends on the type of fracture. Depending on the situation, patients can take weeks to months to recover[13].

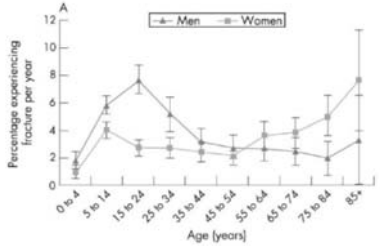


Figure 5-The age group distribution of ankle injurySource:donoldson et al,2008

11 Pijnenburg, A.C., Van Dijk, C.N., Bossuyt, P.M., et al. (2000). Treatment of ruptures of the lateral ankle ligaments: a meta-analysis. The Journal of Bone and Joint Surgery (American). 82, 761-773
12 Kong, Y.K, Lowe, B.D. (2005). Optimal Cylindrical handle diameter for grip force tasks International Journal of Industrial Ergonomics. 35, 495-50
13 Sandelin, J. (1988). Acute Sports Injuries, in: A Clinical and Epidemiological Study Dissertation. University of Helsinki, pp. 1-66

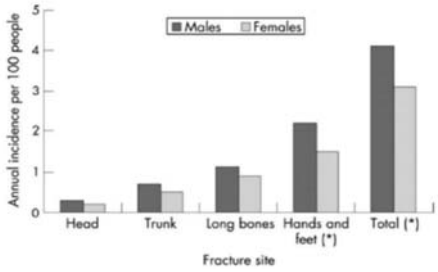


Figure 6-The distribution of different fracture types Source:donolson et al ,2008

3.Features

3.1 Function of crutches

As a balance aid, crutches reduce the load on the legs and lower body. Usually used as a walker to help people with leg, foot or knee injuries. The elderly also often rely on crutches for unstable balance, and walkers are commonly used when they are unable to carry the weight of their body through an injured leg.

In an upright position, crutches are used to help people move. As they go through a long recovery period, they will slowly carry more weight through the injured leg, gradually reducing their dependence on the walker.

More people do not choose wheelchairs because of terrain limitations and the need for other people to take care of them, so crutches are more popular with more people.

However, crutches also have their drawbacks. They require strong arm strength to move safely, as well as adequate balance and coordination of limbs, so they are not particularly suitable for the elderly who are weak or have weak arms.

3.2 The analysis of axillary crutch

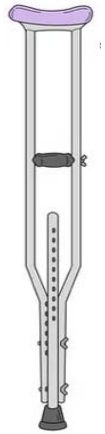


Figure 7-

3.2.1 Axillary crutches

Underarm crutches are sometimes called underarm crutches and are usually made of wood, aluminum, and titanium. Metal crutches usually have spring-loaded fasteners that are used to adjust the length of the hand and the whole. We often think of the axillary crutch as being supported by the armpit. In fact, if the axilla acts as direct support, direct pressure on the axillary area may compress nerves and blood vessels. So, the top of the axillary crutch is usually covered with a sponge or soft rubber to increase friction, prevent the crutch from falling, and cushion the pressure on the patient's chest. Sometimes a portion of it is bent to provide a larger surface area of support.

3.2.2 Applicable users

This product is suitable for patients with various types of motor disabilities, whether temporary or permanent, and can assist them to walk, at the same time, people with paralysis of the lower limbs can also use.

3.2.3 Load-bearing structure

It can reduce the weight bearing of the lower limbs by 70 percent

Figure 8-

3.3 The analysis of walking stick

3.3.1 A walking stick,

The walking stick used to be a symbol of power, a weapon or a tool to help people navigate rough terrain. It can also be used as a fashion, ritual, or status symbol

In modern times, we find that the use of ski poles and blind poles originates from the shape of walking sticks, which are mainly used to provide stability and support for walking. But the disadvantage is obvious: the user must lean forward to transfer lower limb strength to the upper extremity. If use for a long time, inevitable will appear the case of the body rickets.

3.3.2 Applicable users

People with mild arthritis, balance problems, and semi-permanent damage to their feet or legs.

3.3.3 Load-bearing structure

It can reduce the weight of lower limbs by 25 percent

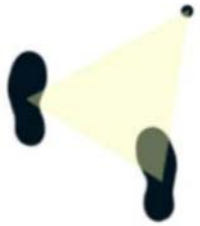


Figure 9-

3.4 The analysis of forearm crutch

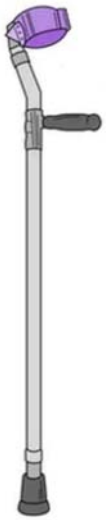


Figure 10-

3.4.1 Elbow/forearm crutches

Forearm crutches are usually made of metal with a metal forearm holder in front. The overall length can be adjusted, the position of the forearm holder can be adjusted, and some have integral folding patterns. Sometimes we see crutches that are sleek and streamlined, and forearm crutches that are creatively made of composite plastic in order to reduce overall weight.

3.4.2 Applicable users

Users with unilateral or bilateral lower limb weakness and unable to walk alternately on the left and right legs after surgery

3.4.3 Load-bearing structure

It can reduce the weight bearing of the lower limbs by 70 percent

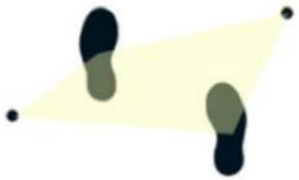


Figure 11-

4. Gait types

4.1 Gait type analysis

4.1.1 A walking stick

When the user uses a crutch, the crutch can be placed on one side of the unaffected leg or used to bear the load of the affected leg.

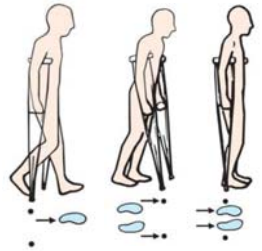


Figure 12-

4.1.2 Four-point gait

A four-point gait is usually adopted by people who can bear some of the weight on their legs. Right, left leg, left leg, right leg. This is the slowest of all gaits, but also the safest because three of the four points are in contact with the ground at any given time.

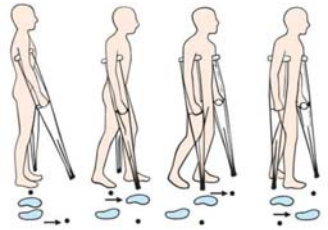


Figure 13-

4.1.3 Two-point gait

People who are able to support some of the weight on their legs but need less support than the four-point step usually use the two-point step. The sequence is right with left leg, then left with right leg.

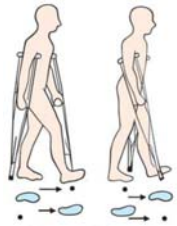


Figure 14-

4.1.4 Three-point gait

The three-point gait is usually used for people who carry weight on one leg. Both crutches are forward and load the unaffected leg at the same time. Then, the unaffected leg moves forward while bearing the weight of the crutch.

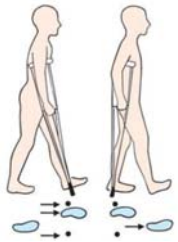


Figure 15-

4.1.5 Walking state

People with non load-bearing injuries usually take the "swing to" gait: lift the affected limb, put two crutches in front of themselves, and then swing the uninjured leg to connect with the crutch. A similar "swing" gait is to extend your legs forward in front of the crutch rather than next to it.

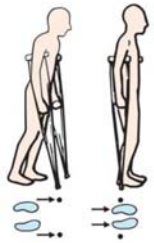


Figure 16-

4.1.6 Stairs

When going up the stairs, first help the uninfected leg, and then help the affected leg and crutches. When going down the stairs, first hold the crutch, then the affected leg and normal leg[14].

14 Crutch from Wikipedia, the free encyclopedia https://en.wikipedia.org/wiki/Crutch

5. Mechanical Structure

5.1 Forearm Crutch on the market

Figure 17-

- Name：Generation Ergobaum
- Brand：Ergoactives
- Unit weight: 2.90 lbs
- Material：High strength aluminum alloy main structure, the surface of the fog black process
- Features：Provides buffering, shock absorption and force feedback to the user. The height and arm length are fully adjustable.
- Disadvantage：Large volume, non-foldable
- Dimensions：Adjustable height - adult: 44 inch - 52 inch
- Price：60 euro
- Release time： 2019

Figure 18-

- Name：Gray Forearm Crutch
- Brand：Drive Medical
- Unit weight: 10.56 lbs
- Material：High strength aluminum alloy main structure, the surface of the fog black process
- Features：Traditional forearm crutches are designed with an arc opening to fix the arm
- Disadvantage：Handrail part of the hard skin will cause wear, need to do some protection measures

- Dimensions：33.47 x 4.33 x 7.87 inches
- Price：48.8 euro
- Release time： 2019

Figure 19-

- Name：In-motion Pro crutch
- Brand：Millenial Medical
- Unit weight: 6.26 lbs
- Material：Alloy Steel
- Features：The ergonomic positioning and design of the grips keep hands and wrists in their natural position, eliminating wrist pain and nerve damage. The unique folding feature allows users to quickly circulate their crutches in and out of use without changing any height adjustments.
- Disadvantage：The height of the hand support can not be adjusted. The overall weight is larger.
- Dimensions：33.3 x 10 x 6.2 inches
- Price：175 euro Release time： 2019

Figure 20-

- Name：SSHHI Forearm Walking Stick
- Brand：SSHHI
- Unit weight: 2.50 lbs

- Material：aluminum,ABS
- Features：In a traditional body design, the curved structure makes the user's posture more comfortable
- Disadvantage：Lack of detail in hand support, Without shock absorbers, it's hard to adapt to all terrain
- Dimensions：Adjustable height - adult: 44 inch - 52 inch
- Price：33 euro
- Release time： 2018

5.2 Axillary Crutch on the market

Figure 21-

- Name：502-1403
- Brand：Duro-Med
- Unit weight: 2.50 lbs
- Material：Lightweight, high-quality anodized aluminum
- Features：Traditional, stable structure, wide handle section, adjustable height
- Disadvantage：It is heavy and inconvenient to carry
- Dimensions：Adjustable height - adult: 44 inch - 52 inch
- Price：80 euro
- Release time： 2020

Figure 22-

- Name：Dynamo Sport
- Brand：DynamoMe Store
- Unit weight: 3.26 lbs
- Material：Alloy Steel
- Features：The bottom has a wide support structure. It provides force feedback and shock absorption. The straps on the back provide support for the patient to walk.
- Disadvantage：The height of the hand support can not be adjusted. The overall weight is larger.
- Dimensions：157 x19 x3 cm
- Price：39 euro
- Release time： 2013

Figure 23-

- Name：crutchair
- Brand：Koreatech
- Unit weight: 2.50 lbs
- Material：ABS,foam,plastic
- Features：Traditional, stable structure, wide handle section, adjustable height
- Disadvantage：It is heavy and inconvenient to carry
- Dimensions：Adjustable height - adult: 44 inch - 52 inch
- Price：80 euro
- Release time： 2020

- Name：Drive Medical Aluminum Crutch
- Brand：DR
- Unit weight: 2.50 lbs
- Material：aluminum
- Features：Comfortable, durable underarm pad and hand grip,Double extruded

center tube provides additional strength to weight-bearing areas

- Disadvantage：axillary crutches might have been due to artificial stimulation of the heart due to the contact of the top of the axillary crutch with the thoracic cage.bottom is unstable
- Dimensions：38 x 4 x 10 inches
- Price：30 euro
- Release time： 2020

5.3 Stick of Cane in the market

Figure 24-

- Name：stick chair
- Brand：The original
- Unit weight: 1.2 lbs
- Material：aluminum
- Features：Foldable, compact, single point floor support, seats,light weight
- Disadvantage：Can not be applied to all terrain, poor stability, bad balance structure
- Dimensions：35.6cm*5cm
- Price：22 euro
- Release time： 2020

Figure 25-

- Name：Folding Walking Cane
- Brand：Ohuhu
- Unit weight: 1.15 lbs
- Material：Aluminum alloy
- Features：Traditional,Foldable and equipped with LED lights.360 degree ANTI-SLIP pivoting base provides easy walk on all terrain.

- Disadvantage：Users have to be bent over all the time to use the crutch. The handle doesn't fit the palm well enough.
- Dimensions：Adjustable height - adult: 33-37 Inch
- Price：23 euro
- Release time： 2020

Figure 26-

- Name：StrongArm Comfort Cane
- Brand：Strong Garm
- Unit weight: 1.7 lbs
- Material：high-quality light-weight aluminum,foam
- Features：offers a cushioned, forearm-bracing "cradle" that stabilizes the wrist, making the cane feel like a solid extension of the arm. When standing from a seated position the cane helps provide added support so users can easily stand up by their own.
- Disadvantage：The point of force changes with the height of the person, and the structure of the hand support needs to be adjusted to accommodate everyone.
- Dimensions：37 x 7 x 6 inches
- Price：67 euro
- Release time： 2019

Figure 27-

- Name：RMS Quad Cane
- Brand：RMS Royal Medical Solutions
- Unit weight: 1.60 lbs
- Material：Aluminum
- Features：The quad base provides superior stability and traction on any surfaces including smooth or uneven floor or concrete pavement. Each prong is covered with a anti slip rubber cane tip for extra stability and safety. The quad base makes it a self standing cane which eliminates falling or dropping on the floor. Disadvantage：The Quad Base also makes it difficult for users to walk on stairs and uneven roads.
- Dimensions：28 x 8 x 5 inches
- Price：29 euro
- Release time： 2018

6. Design Concept

6.1 Ideas based on scenarios

Figure 28-

This project conducted a small market survey and analyzed the above products in particular. And based on the experiments of multiple scenarios of using the forearm crutch, I found a scenario in which the forearm crutch was inconvenient to use in daily life. Starting from the use scenario, starting from solving the actual use problem, this inspired me.

Scene 1: Inevitably, users of the forearm crutches often have to switch between walking and sitting. According to the design instructions for most crutches, the first step is to move your buttocks toward the edge of the seat and hold the forearm crutches in both hands while finding a point of force forward or backward. Use the weight of your upper limbs to press down, creating a counterforce that allows you to stand up. In the course of the survey, many crutches users had experienced falling over trying to get up from their chairs.

Imagine when you fall down on a ski run, you have two poles hanging from your arms, and you try to get up off the ground, you can use the strength of your leg muscles, but it's still a very hard thing to do.

For crutches users who cannot use leg strength for support, the action of standing up from the chair requires very high upper limb strength and balance of the users, especially the obese users. The concave surface of the wheelchair also makes it difficult for the user to move his body to the edge of the seat. The user agonized over whether or not to sit down briefly, sweating a lot each time he or she stood up, and tried many times to succeed.

The second scenario: Based on the life needs and psychological needs of crutches users, crutches users do not want to be a person who needs to be taken care of 24 hours a day, which will increase their psychological burden. However, users of forearm crutches need to grasp the armrest in any scene to move. Due to the limitation of the overall height of forearm crutches, they cannot support the body with chest and armpit like users of underarm crutches, and free their hands to carry things, shake hands and brush their teeth. The only

way is to approach the object with your entire body along with the forearm crutch. So free hands, for them is also a very important issue.

6.2 Concept

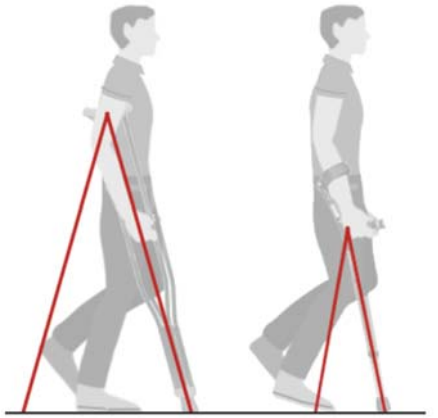


Figure 29-

Having identified the problems to be solved, I set several design principles in this direction to ensure the usability of the product design

Principle of functional rationality: due to the lack of physiological function of patients, there are certain obstacles when using conventional products. Therefore, while meeting the function, it should also meet the user's behavioral needs, psychological needs and aesthetic needs

Principle of simplicity: for long-term contact and friction products, avoid sharp corners, protruding objects, function and form should be organically combined together, and minimize decorative form

The principle of easy to learn and easy to use: for products with high frequency and unobstructable functions, the principle of zero learning cost is advocated. The use of all extended functions follows the user's habits and appears in an appropriate position

Safety and reliability: eliminate potential safety problems, and use more reliable materials to support the functionality of the product.

Quality is consistent with price: more emphasis on reliable quality, convenience, practicality, economy, rationality, comfort and safety

Forearm Crutch is designed to be more ergonomic for patients with lower limb injuries, making it easier and safer for patients to use. (1) The bottom of the crutch must have an anti-slip device. The friction between the rubber and the ground is very large, which can keep the crutch light and steady when landing, and not easy to slip. (2) The handle of crutches should be comfortable to hold, and the material of the handle should be as full as possible. There are some convenient functions on the handle, so that the crutches can better serve patients. (3) Elastic design, the length of the crutch should be adjustable. When the patient stands up straight and holds the crutch parallel to the leg, the arm should be at a 30 degree Angle with the crutch. If the forearm structure is too long, the handle will push the

wrist too high, which makes it uncomfortable for the patient to hold it. The handle should be longer than the width of the palm of your hand so that your wrist is relaxed when you hold it. (4) Material, generally choose strong, durable, not easy to deformation, light crutches. The material weight should be less than 250g, the surface should not be too smooth, and it should have a comfortable and safe feeling in the hand.

6.3 Structural Decomposition

After investigation, it is decided to redesign forearm crutch. First, analyze and evaluate forearm crutch on the market

The key components of forearm crunch are listed in the figure. First, we need to understand the relevant structures in the crutch design and the corresponding functions of different structural components. By analyzing the characteristics of the function, we can find the existing problems and potential improvement opportunities, so that we can determine the direction of improvement.

6.3.1 Arm cuff

Arm cuff is an important part of forearm crutch. Its main function is to help patients fix their forearm when moving forward. There are two types of cuffs: open and closed. Closed crutches have a V-shaped opening that allows the forearm to slide out when the patient falls.

In the past few decades, there has been no major change in the work part of forearm crutch. Relatively speaking, the design of this arm sleeve tends to be perfect, so I decided to keep this design without major changes. Generally, there are two commonly used arm sleeve sizes, one is large and the other is small. The small one is generally provided to teenagers. Many people choose to open the arm sleeve, because the two arm sleeves can not adapt to the arm size of most people, and they are often too small and too tight. So we need to design a wider range of adjustable arm sleeve.

6.3.2 The arm support

The fulcrum plays an important role in connecting the arm sleeve and the upper tube. It allows the user's forearm to rotate around a pivot connection in a single dimension, allowing the patient to rest the arm on a laminate opposite the V-shaped opening. According to the previous research and analysis, the joint of cutting fulcrum is relatively fragile and fragile, which needs to be discussed in the redesign stage[15].

6.3.3 Ferrule

The ferrule below accommodates different terrain, but there is usually only one

15 Sarmasti Emami, M.R., Jamali, S.5. (2009) Investigation of ergonomic issues in cruto design and present an innovation. Iran University of Science and Technology, Tehran. Schlick, E. (1917 Oct.23). Walking-stick. United States patent US 1,244,249

round ferrule made of rubber, in which case the space is designed to be more spacious. Ensure the balance of crutches, so that the body is better coordinated with the crutches.

6.3.4 Handle

Some handlebars are too thin to be held by patients, and the material of the handle is too rough, which will cause pain, numbness and indentation in the palm. This is why patients always tend to take a break and stretch their fingers to relieve the pain.

6.3.5 fittings

Long-term repeated use will cause the wear of the connecting parts, thus affecting the sprung function, such as the pressed pin can not pop out, so in the design, it should be carefully considered.

In addition to the handle, other aspects of crutch design have also been studied. Bauer et al.(1991) believed that an appropriate length of crutch could effectively reduce energy consumption and prevent injury during crutch movement. The results confirm the researchers' hypothesis and provide specific guidelines for users to choose the ideal crutch length based on height. Mullis and Dent(2000) initiated a study to investigate the effect of Crutch length on energy expenditure while walking with Forearm Crutch. They reset the length of the crutches by adding or subtracting 2.5 centimeters, according to traditional guidelines, and compared those adjusted crutches to normal crutches under walking conditions. The results showed that while adjusting length from traditional guidelines resulted in an increase in age prediction of maximum heart rate, oxygen rate, and cost, the difference could be ignored if the deviation was too small. Pradhan et al.(1990) suggested that the weight of crutches also affected the walking of amputees with crutches. The researchers came up with mathematical models related to the user's height, weight and crutch weight from an ergonomic point of view.

Figure 30-Fulcrum for the forearm Source : Life-Medic , 2009

7. Prototype Design

7.1 Hand-painted

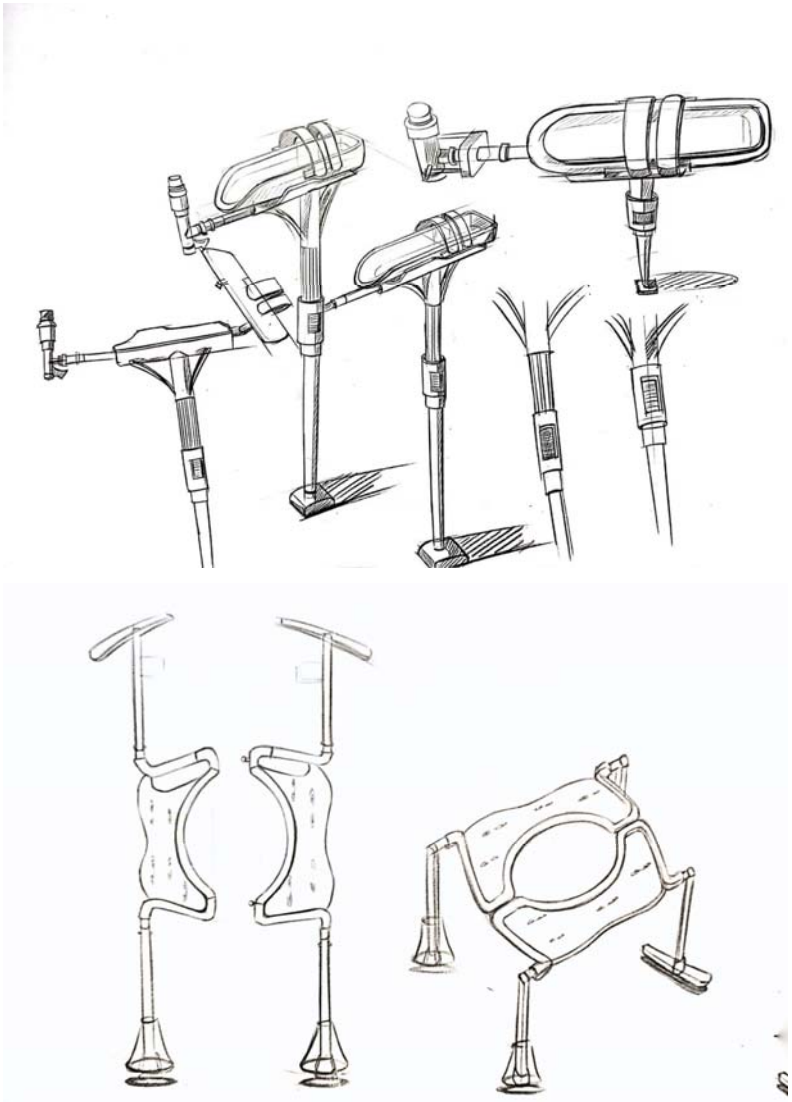
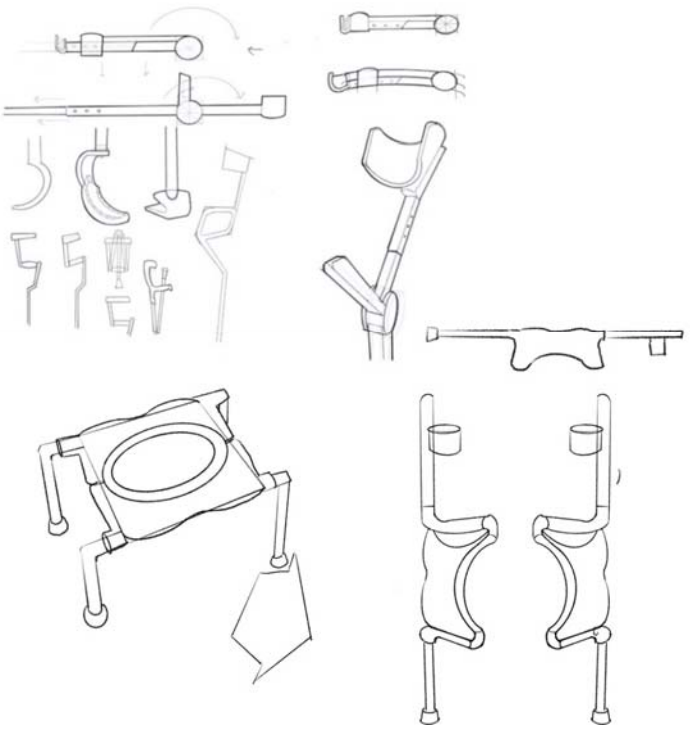
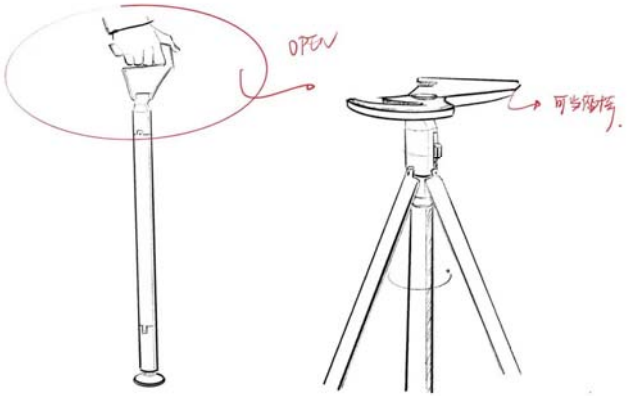


Figure 31-

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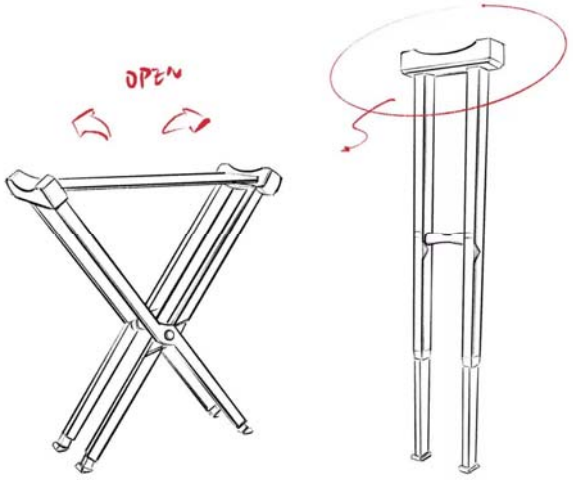
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8. Overall Design

8.1 Aesthetic Design

Three colors, black, white and metallic, are used to match and combine, and the combination without color reflects the concise aesthetic concept. And I hope to use this color combination to express a original, stable and balanced aesthetic expression.

The overall use of streamlined design framework, consistent with the color expression of natural, integrated design language.

8.2 Structural Design

After analyzing the structure of the other forearm crutches, the strength to rise from the chair is mainly supported by the side front and side back. In order to enable the cane user to sit up vertically from the seat, a component containing a spring is installed in the middle of the cane. Press the button on the upper part of the forearm cane to shake hands, and the child lock on the spring part will open. The user can press the frame of the cane to the appropriate height while sitting down. When the finger is released, it will lock the child lock. When the user wants to stand up, erect the cane vertically on either side with the elbows supported on the horizontal surface. Press the button above the handshake, and the spring will expand, giving a reaction force to the vertical rise, helping the user to stand up easily from the chair.

In order to free the hands of the forearm crutch user, a lock arm structure is installed above the horizontal elbow support structure. When the paddles are pulled under the grip part, the two-part lasso is unlocked and the user's hands can move freely with the elbow supporting the crutch

Elastic design, the length of the crutch should be adjustable. When the user stands straight and holds the crutch parallel to the leg, the arm should be at an angle of 30 degrees with the crutch. If the crutch is too long, the handle will push the wrist too high, and the user is uncomfortable to hold it. The length of the crutch handle should exceed the width of the palm, so that the user can hold it and relax his wrist

9. Component Design

9.1 Handle Design

It can be said that the diameter of the handle is often widely studied. The design of the handle should minimize the stress and maximize the grip force, which is intuitively important for the user's convenience. A study by Yakou et al. (1997) found that the ideal handle size for men is 30-40cm and that for women is 26-36cm. In terms of comfort, the larger size of 40mm is widely suitable for all crutch users. In addition to diameter, the contact area of the user's palm is also very important. Cylindrical crutches and wide-handled crutches have a very similar load distribution, with a wider handle having a larger surface area and less focus pressure.

9.2 Forearm structure design

The tilt of the tilt handle is another important area to pay attention to. A study by Wiley(1960) found that, compared with the traditional horizontal grip, the tilted grip at the right Angle made the user feel more comfortable when walking with crutches. A similar experiment was conducted by Segura and Scholar(2005). They made a pair of crutches and set the handle at 17 degrees horizontally. The force, position and comfort of standard crutches and modified crutches were compared in 8 healthy volunteers.The results show that the grip force of the improved design is basically the same as that of the standard design, but the position of the improved design is significantly different from that of the standard design. The mean force position of the modified handle was 27.9mm from the center of the crutch, and this increased to 52.9mm when the test subjects were changed to the standard design (Segura and Scholar, 2005). As for comfort, five of the eight participants preferred standard handles, which the researchers also insisted was due to inappropriate materials (wood) and size (too large). They believe that the angled handle distributes the force along the center of the palm, rather than just concentrating on the front of the HANC, making the patient feel more comfortable[16].

16 Wiley, B.C. (1960). Crutch with Sloping Handgrip. J.A.M.A. 7, 694-695

9.3 Spring Assembly design

In the damping device, the spring is in contact with the damping rod so that the spring rate is adjustable. A grip pad is also attached to the support for stability during movement. The cuffs are moulded in av shape with widths ranging from 12.7mm to 31.75mm at the top and smaller widths from 2.54mm to 10.16mm at the bottom. The designers hope the design will accommodate different sizes of elbow.

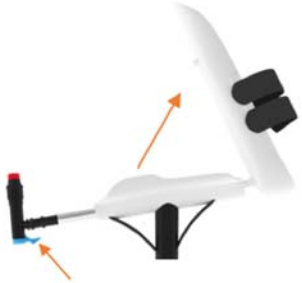
9.4 Reflective belt design

On the side of the crutch, a passive fluorescent lamp belt is installed, so that the vehicle can see the users with inconvenient movement in the case of dark light.

9.5 Button Design

Press the spring switch, because there is a press action, let the user more easily associated with vertical movement, reducing the cost of learning.

The movements associated with the paddles are deconstructing and unlocking, which is in line with the user's habits. The user can use his little thumb to move the paddles and move his arm at the same time. When the user wants to continue walking, the arm assembly will be inserted back, the horizontal part of the support will be locked with the elbow again through the buckle, and the paddles will return to the previous state.



9.6 Ferrule design

The special rubber ring bottom can adapt to a variety of rugged terrain

10. Material Selection

10.1 Titanium alloy material

The attributes of crutches include appearance, weight, length and comfort. Since most crutches are adjustable in length and comfort has been analyzed in detail above, the focus of this section will be on appearance and weight. It seems that the appearance of the cane has not changed significantly over the decades since Loftstrand invented the modern crutch in 1945. With the development of technology in recent years, more and more crutches with novel shapes gradually appear on the market. Still, these innovation crutches don't seem all that common in today's society. Most people still use traditional glasses to help them walk. Fewer referrals from hospitals may be one reason. As a medical device, however, do people really care about how crutches look? According to the results of the questionnaire, more than two-thirds of the participants were very satisfied with the current shape, believing that beautiful appearance was not that important to the design of crutches. Therefore, improving the appearance of crutches is not the focus of further research[17].

The average weight of medical crutches currently available in hospitals and on the market is around 520 grams each. As material technology advances, crutches become lighter and lighter. Its use of new magnesium alloy instead of traditional plastic and metal materials, greatly reducing the total weight of crutches, is currently one of the lightest materials on the market. In fact, even though the current weight of medical crutches is accepted by users, 95 percent of respondents thought the weight was just right or a little light. Only 5 percent thought crutches were too heavy. Therefore, the weight of the redesigned crutch in this paper does not exceed the weight of the traditional crutch, which is enough to meet the needs of users.

In many materials, after comprehensive analysis, we decided to use excellent magnesium alloy materials in crutches, chair support and chair surface. Compared with aluminum alloy and stainless steel, magnesium alloy products have the advantages of :(1) rugged and durable, high strength and strong load-bearing capacity. The specific strength of magnesium alloy is higher than that of steel, and the specific stiffness is close to that of steel and aluminum alloy, and the unit mass can withstand more loads. (2) Light weight, magnesium alloy is the lightest metal in the applicable metals, is 2/3 of aluminum, is 1/4 of

17 http://www.sportstek.net/rec400.htm [Accessed on the 15th July, 2010 Stallard, J, Sankarankutty, M., Rose, G.K. (1978). A Comparison of Axilary, Elbow, and Canadian Crutches. Rheumatology and Rehabilitation. 17, 237-239 Subramony, S.H. (1989). Electrophysiological findings in crutch palsy. Electromyog clin. Neurophysiol 29, 281-285

iron, easy for users to carry at ordinary times, will not cause additional burden. (3) In the elastic category, the magnesium alloy receives half more energy than the aluminum alloy when subjected to impact load, so the magnesium alloy has excellent seismic and shock absorption function. When the user touches the hard ground with the crutch, the ground can buffer the vibration facing the arm. (4) As a casting, magnesium alloy has good castability and dimensional stability, easy to process, low rejection rate, and reduced production cost.

Since the melting point of magnesium alloy is lower than that of aluminum alloy, the formability of pressure casting is good. The tensile strength of magnesium alloy castings is equivalent to that of aluminum alloy castings, generally up to 250Mpa, up to more than 600 MPa, and the yield strength and elongation are not different from that of aluminum alloy. The stability of magnesium alloy is higher than that of high-pressure casting, and the dimensional accuracy is high, so it can be machined with high precision. Die casting can obtain clear patterns, patterns and words on the surface of castings. It is suitable for manufacturing small, thin-walled and complex castings with inlays, and can obtain satisfactory appearance quality.

The products are made of magnesium alloy and other materials, and the detachable and tensile functions are realized through snap connection and screw nut connection. Modern buttons are placed at the handle to achieve a more humanized effect.

10.2 Rubber material

The weight of crutches is always determined by the material they are made of. Basically, the basic materials for Forearm Crutch include thermoplastics (such as polyethylene) for armcovers and handles, rubber for clasps and ferrule, etc.

11. Model making

11.1 Production Process

12 . Test verification

12.1 cenario Usage diagram

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