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ORIGINAL

Urban mobility and accessibility. Design of a body support object for people with physical impairments: Design for personal urban mobility

Movilidad urbana y accesibilidad. Diseño de un objeto de apoyo corporal para personas con deficiencias físicas: Diseño para la movilidad urbana personal

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ABSTRACT

Urban mobility for disabled people in Córdoba reveals an importance lack of infrastructure in order to make feel more comfortable and safer when they go through the city. The main purpose of this project is to design a body support object which bring a solution to exceed all the physical urban and furniture barriers that disabled people have. Given the importance of this topic around the world, we considered how we could create a solution to improve their mobility and even recover after surgery that these people have to deal daily. The present investigation, we analyzed the different difficulties that a person with reduced mobility has. We found that not only the lack of infrastructure and accessibility in urban areas generate difficulties to them but also the oversize of the objects used for mobilization. Regarding this, when asked, people answered that using certain orthopedic objects bring others physical damages to other parts of the body, limiting more their daily activities and having to depend on the help of other person. After this, we carried out an analysis of existing products in the market, which gave us a guideline on how to deal with the problems posed. Then, we took certain qualities of other products that are introduced to other non-health areas. Finally, as a result of the research, a proposal was obtained an orthopedic crutches that directly benefits people with a particular physical deficiency, whether temporary or permanent, so that they have the possibility of improving their mobility and even their recovery, and in this way have a better quality of life.

Keywords: Accessibility; Independence Mobility; Physical Impairment; Orthopedic Crutches.

RESUMEN

Actualmente, en el marco de movilidad urbana de la ciudad de Córdoba, existe la cuestión que ciertos ciudadanos presentan serios problemas para circular de manera cómoda y segura por los entornos urbanos. El presente trabajo tiene como principal finalidad dar una solución de superar estas barreras y mobiliarios urbanísticos, a través del diseño de un objeto de apoyo corporal para personas con deficiencias físicas. Dada la importancia que tiene este tema a nivel mundial, se planteó cómo se podía generar una solución para mejorar la movilidad e incluso su recuperación posoperatoria que presentan estas personas en su vida diaria. En la presente investigación, se analizó las distintas dificultades que tiene una persona con movilidad reducida. No solo nos encontramos con la falta de infraestructura e inaccesibilidad en ámbitos urbanos, en la cual les generan más dificultades que las personas ya padecen, sino también que, al utilizar ciertos artefactos de apoyo corporal para movilización, dan resultado que el tamaño de las mismas repercuten la circulación de manera confortable. Para dar sustento a lo recaudado, se entrevistaron a personas con estas patologías, que nos comentaron que han presentado consecuencias y daños físicos en otras partes del cuerpo, limitaciones y dependencia en la ayuda de otra persona para realizar actividades cotidianas por el uso de ciertos objetos ortopédicos. A continuación, se realizó un análisis de productos existentes en el mercado que dieron pautas de cómo enfrentar la problemática planteada, y se tomaron en cuenta ciertas cualidades de

productos que están abocados a otras áreas no referentes a la salud. Finalmente, se obtuvo como resultado de la investigación, una propuesta de muleta ortopédica que beneficia directamente a las personas que padecen una deficiencia física particular, ya sea temporal o permanente, para que tengan la posibilidad de superar las limitaciones que encuentran en su movilidad e incluso reducir el tiempo de su recuperación.

Palabras clave: Accesibilidad; Movilidad Independiente; Deficiencia Física; Muleta Ortopédica.

INTRODUCTION

Breakdown of the problem

What is physical disability?

"Physical disability affects people with problems such as amputations, malformations, paralysis, loss of mobility, or chronic diseases, which prevent them from leading a normal life or make it necessary to use certain technical aids".[1,2,3] This means that, for a temporary or permanent period, the person has this functional limitation that affects their ability to perform certain activities in a society that presents severe limitations and barriers.[4,5,6]

How are the lives of people with physical disabilities affected?

The lives of people with physical disabilities or people who suffer from temporary loss of mobility lead to emotional reactions (anxiety, sadness, depression, distress, anger, rage, apathy, crying, despondency, hopelessness) that are normal and not pathological, unless these negative emotions persist over time. This also means that the person has to face changes in their life and in the activities they carry out in their daily life, which can have consequences for their work, social activities, transportation, role changes, emotional changes, financial difficulties, and reduced leisure activities, among others.[2,7,8]

What types of urban barriers and limitations are found in the city of Córdoba for people with physical disabilities?

According to Law 24.314 (1994):

Accessibility is understood to mean the possibility for people with reduced mobility to enjoy adequate conditions of safety and autonomy as an essential element for the development of daily life activities, without restrictions derived from the urban, architectural, or transportation environment, for their integration and equal opportunities. The city of Córdoba has experienced enormous growth in recent years with regard to civil works, commercial premises, hospitals, transportation, among others.[9,10]

Unfortunately, it does not comply with Law 24.314 because many urban, architectural, or transportation projects are not accessible to everyone who travels around the city. The physical barriers that exist today in the city of Córdoba are as follows:

- Boarding and alighting from public transport.
- Public transportation stops.
- Non-adapted public transportation.
- Lack of access or paths to buildings and squares.
- Poorly designed pedestrian walkways that are rarely maintained. There are cracks, breaks caused by tree growth, and old layers of cement mixed with new ones.
- Lack of or poorly constructed access to the sidewalk on a street.
- Broken or poorly adapted steps, ramps not built.

Analysis of the relationship with the environment

A person with a temporary or permanent physical disability must think about and organize their daily route from their home or wherever they are to reach their destination, and plan their route without having to pass through any physical barriers that block their path or aggravate their situation. This situation requires a lot of time, both to think about going out beforehand and to overcome any obstacles that may arise. In other words, they must carry out their routine and daily life based on the difficulties that arise in urban environments. However, despite the considerable population growth in recent years and the favorable measures taken for the city in urban, architectural, and transportation areas, insufficient attention has been given to access to buildings, public paths, and transportation routes to make them accessible and suitable for all residents and tourists. In this regard, we primarily involve people with physical disabilities, pregnant women, people who travel with their children in strollers, the elderly, among others, who face the greatest difficulties. Those with any of these conditions seek options within their reach to optimize their quality of life and improve their mobility or recovery. However, these obstacles make it even more difficult to achieve.[11,12]

Needs analysis

With regard to people with physical disabilities, we can say that they generally depend on a body support product or orthopedic device that facilitates and provides better mobility for that person. There are anthropometric measurements that measure people using body support products, which influence better movement and maneuverability in environments. However, these body support devices can also be a limitation or impediment to comfortable movement in physical and urban environments.[13]

The urban barriers mentioned above and the street furniture found in environments and transportation limit a person's freedom of movement, since, when using these body support devices, their size also affects their comfortable mobility.[14]

Given that these products are highly dependent on these individuals, we can also note that, in general, in their daily use, there are people who generate intolerance, other physical repercussions, or limitations in body functions such as the hands (necessary for use of the product) and certain emotional consequences. This results in people not feeling completely satisfied with the use of the body support device.[15]

Scope

The purpose of this study is to identify the physical difficulties faced by people with reduced mobility when moving around in urban environments, taking the city of Córdoba as the limit of its scope. Therefore, it will focus on the places where there are the greatest problems and on urban transport with regard to access, as these are the places where people have the greatest difficulties. A specific region has been selected in order to obtain more specific results, which will be beneficial in the future and can be applied in other parts of the country.

This research aims to directly benefit people with physical disabilities, whether temporary or permanent, so that they have the opportunity to improve their mobility and even their recovery. Many of these residents travel on foot or by urban transport in areas with heavy foot traffic, which, due to certain problems found in urban areas, has a negative impact on these people, as it requires them to spend time planning their trips from one destination to another, as well as overcoming certain physical and inaccessible obstacles that arise when traveling.

The objective of this research is to develop a proposal that meets the expectations of people who are truly seeking to optimize their quality of life and have a better chance of improving their mobility or recovery. Therefore, a body support device will be developed to help improve mobility in the face of the physical urban obstacles found in the city of Córdoba.

How can we use an industrial design product to help people with certain physical disabilities move around the city of Córdoba without difficulty or consequences due to physical urban and street furniture barriers?

Objective

To design a body support product that provides better mobility for people with reduced mobility when accessing physical environments and urban transport.

METHOD

Figure 1. Research design

Design

This research presents the realities of people with walking abilities as a problem, seeking to understand their behaviors, attitudes, and limitations in their mobility. Therefore, the aim is to contribute to improving their mobility and thus reducing the difficulties they face. This work is considered to be explanatory in scope, seeking to better understand the problems that cause this situation and then, based on the results obtained, to achieve an effective solution. The following questions need to be considered throughout the process, as they will be of great help at each stage.

What contributions can be made so that all people can travel from one destination to another safely and comfortably in urban environments? How can this have a positive psychological and physical impact on the individual?

The research approach will be mixed, as it will be a process in which quantitative and qualitative data will be collected, analyzed, and linked in a series of studies to respond to the problem posed. On the one hand, it is defined as qualitative, since an anonymous survey will be conducted among a number of people in the city of Córdoba to understand human behavior, the emotions they experience when walking, and whether there are reasons why traveling around the city has an impact on their daily lives.

On the other hand, it is defined as quantitative because, based on one of the questions in the general survey that will be conducted on the issue raised, the answer that obtains the highest percentage in that question will provide a guideline for the direction we will take, that is, which specific person with walking ability and body support element we will focus on. This approach will be taken because there are countless types of body support devices for certain fractures or immobility of any part of the lower limbs.

Likewise, with the data obtained, interviews will be conducted with three types of people to give us more details about the issue. First, three people with ambulatory capacity who have or have had this difficulty will be interviewed, with the aim of gaining a deeper understanding of their situation and providing a clearer answer to the questions. In addition, a series of questions will be asked of a professional in the field of urban mobility in the city of Córdoba, in order to provide us with information and learn more about this issue, with reference to how the city is adapted for people with ambulatory disabilities. Finally, we will talk to a physical therapy professional who will directly contribute their experience with patients undergoing rehabilitation, as well as their knowledge related to the subject.

In conclusion, the research design will be non-experimental and cross-sectional, as it observes existing situations in which the results are not manipulated.

Participants

In this study, the sample will include, on the one hand, people aged 6 and over, regardless of gender, who live in and move around the city of Córdoba, and, on the other hand, three people with reduced mobility in their lower limbs. Finally, two professionals with different points of view will be included: one person involved in lower limb rehabilitation and another person who works in urban mobility in the city of Córdoba.

Design of the instruments

Data collection will be carried out using a series of instruments. First, an anonymous general survey with closed questions will be conducted to collect data and information from people who will be asked, mainly, if at any time in their lives they have had complications or limitations in moving comfortably and safely around the city of Córdoba. In addition, three personal interviews will be conducted using a semi-structured approach. One of these will be conducted with the same questions to three people who are able to walk. The other interview will be with an expert in the field of urban mobility in the city, to obtain more information on the current urban barriers in the city. Finally, a personal interview will be conducted with a physical therapy and kinesiology professional, who will share their own experience working directly with patients who need post-operative rehabilitation.

This will provide us with more in-depth information related to the problem, which will be a great contribution to the development of the product in the future.

Data collection

This section shows the selection of questions that will be asked, on the one hand, in the general survey with the results obtained, and, on the other hand, in the personal interviews, the questions addressed to three people with ambulatory capacity, the professional in the area of urban mobility in the city of Córdoba, and the professional in physical therapy and kinesiology. The results of the personal interviews can be found in the annexes section.

Questions for the anonymous general survey:

1. Do you consider yourself a person who constantly walks around the urban areas of the city of Córdoba?

2. Have you ever had a walking limitation that made it difficult or impossible for you to get around the city?

3. Do you consider the city of Córdoba to be adapted for anyone to walk and move around urban environments?

4. What do you think are the physical urban limitations that make it most difficult for you to get around on foot? You may select more than one answer.

- Large crowds of people walking
- Access to public and private buildings.
- Poorly designed pedestrian walkways that are rarely maintained (cracks, uneven surfaces).
- Failure to build paths that comply with regulations when there are temporary public works.
- Boarding and alighting from public transport
- Urban transport stops.
- Cracked or poorly constructed steps in urban environments.
- Failure to create uneven surfaces, respecting crossings and curb cuts for sidewalk access.
- Inaccessible trails and paths, not respecting their width along their entire length.
- Other.

5. What were the possible consequences of these physical urban barriers? You may select more than one answer.

- Bad mood.
- Irritability.
- Anxiety.
- Anger.
- Complaints.
- Distress.
- Intolerance.
- Arriving late at your destination.
- Tripping or slipping.
- Other

6. Have you ever had a temporary disability (cast, pregnancy, injury, respiratory illness) or do you consider yourself to be of an age where it has hindered/hinders your ability to move comfortably around the city?

7. If yes, what type of body support method/product did you use?

- Walking stick.
- Crutches.
- Walker.
- Wheelchair.
- I did not move around.
- Other

8. If yes, were there times when you couldn't tolerate using the body support product (discomfort, size, etc.)?

9. Looking at the figure, do you consider comfortable accessibility to be important for anyone moving around the city?

Source: The Voice of The Interior 2018[3] https://bit.ly/2KghohD

Figure 2. Difficulty of accessibility for people with physical disabilities

Questions for the personal interview with people with walking ability:

1. What physical difficulties do you currently face?
2. How did this immobility come about?
3. Do you use any physical assistive devices? Which ones?
4. How do you feel when using that mobility aid?
5. Do you have difficulty overcoming or dealing with obstacles in your home or indoor environments when you move around with your mobility aid? Give examples.
6. Do you encounter physical barriers in urban environments when you are out and about? Please give examples.
7. What possible emotional or physical consequences do these physical urban and furniture barriers have on you?
8. Would you change any element or function of the device you are currently using?

Questions for the personal interview with the Urban Mobility professional:

1. What are the premises for organizing urban mobility in the city of Córdoba?
2. How is the city of Córdoba adapted in terms of its traffic and mobility system for people with physical disabilities?
3. Have measures been taken to improve the mobility of these people?
4. What do you think is the main barrier or barriers to the mobility of these people in the city of Córdoba?
5. Do you consider urban furniture to be a physical limitation for these people?
6. What measures can be taken to improve the quality of life of these people?
7. Are any measures currently being taken to address the physical limitations faced by people with physical disabilities in Córdoba?

Questions for the personal interview with the rehabilitation professional:

1. What is your specialization in terms of rehabilitation?
2. What general measures are taken in terms of rehabilitation for a walking disability (fracture, elderly person, difficulty walking)?
3. Is it necessary to consider an analysis in cases where there are psychological consequences when a patient begins and undergoes rehabilitation?
4. What are your observations of the city of Córdoba in urban areas with regard to accessibility, especially for people with ambulatory disabilities?
5. Is it possible that rehabilitation may be affected by undue effort in moving from one place to another, for example, by bus (home-work)?
6. What major changes have you seen in personal mobility devices throughout your professional life?
7. If you had to select two of the body support devices that cause the most difficulty for people in terms of discomfort, which ones would they be?
8. What is your opinion on the structure and functioning of conventional crutches?

Data analysis

For the purposes of the research, we took the most relevant data from the general survey, to which 95 residents of the city of Córdoba responded. It should be noted that most of the people who responded to the survey, as well as the former secretary of transportation for the city of Córdoba, believe that the city of Córdoba is not prepared for walking in urban environments. In addition, it was observed that most people did not or do not have the ability to walk. In any case, healthy people report certain limitations in their ability to walk in urban environments, which has psychological consequences and causes problems in their daily lives. These limitations are the physical urban barriers that exist in the city. This is even more serious because if people in good health show these limitations, people with motor disabilities also experience these conditions, but the degree of difficulty and problem is even higher. In addition, we can highlight what the former secretary commented, that the main barrier is the lack of a public policy that maintains conditions and generates civic awareness (in terms of respecting the rules) and solidarity with neighbors, since it often makes it difficult for those with disabilities or who are in "vulnerable" age groups in this regard to get around.

In one section of the survey, we emphasized that the highest percentage of responses to question No. 7 would indicate the type of body support device we would focus on. This response showed us that of the twenty-seven people who responded and who have had or currently have mobility issues, half of them used crutches. Therefore, this provides us with a basis for concluding that crutches are the most in-demand body support device in the city of Córdoba.

In addition, it can be concluded that more than half of the people who have used a body support product

consider that they present a certain intolerance in their use. This means that hospitals or rehabilitation centers in the city of Córdoba do not offer a certain level of innovation in body support devices to make people feel more comfortable when using them.

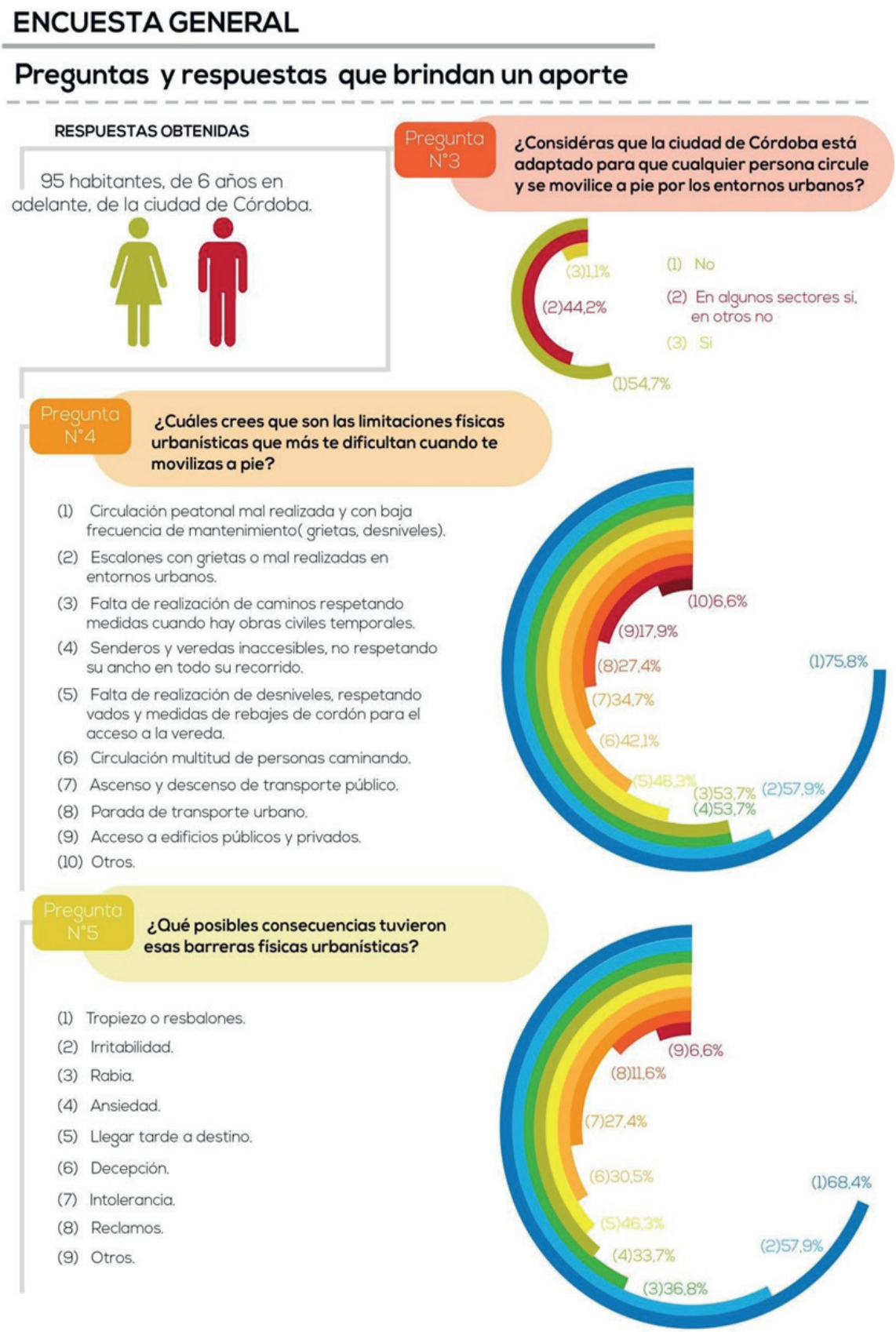

Figure 3. Summary of survey 1

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Figure 4. Summary of survey 2

Based on these results, we decided to focus on an analysis of people who have used or currently use crutches. For this reason, we interviewed three people individually and personally, and we can say that they shared similar information about the problem. In the following figure, we highlight the most important points they made about the use of crutches.

In short, these individuals experience certain intolerances due to their difficulty in moving around and overcoming obstacles, such as stairs and uneven surfaces, whether at home or in urban environments. This causes them greater physical strain than they already experience, which also has consequences that are unhealthy for them. In addition, each of them said that it would be useful to improve the contact between the armpits and the crutch and to have the possibility of greater stability and adaptability to any surface, whether regular or irregular.

Figure 5. Interview summary

Finally, we can highlight what the person in charge of rehabilitation told us, which provided us with input for our research. It should be noted that, in the event of undue effort to overcome urban or furniture obstacles, this may not only delay rehabilitation but also aggravate the injury, leaving a possible permanent disability in that part or tissue of the body. Therefore, in this present work, we will establish that the person can overcome this obstacle without having to make a physical effort and without generating emotional consequences.

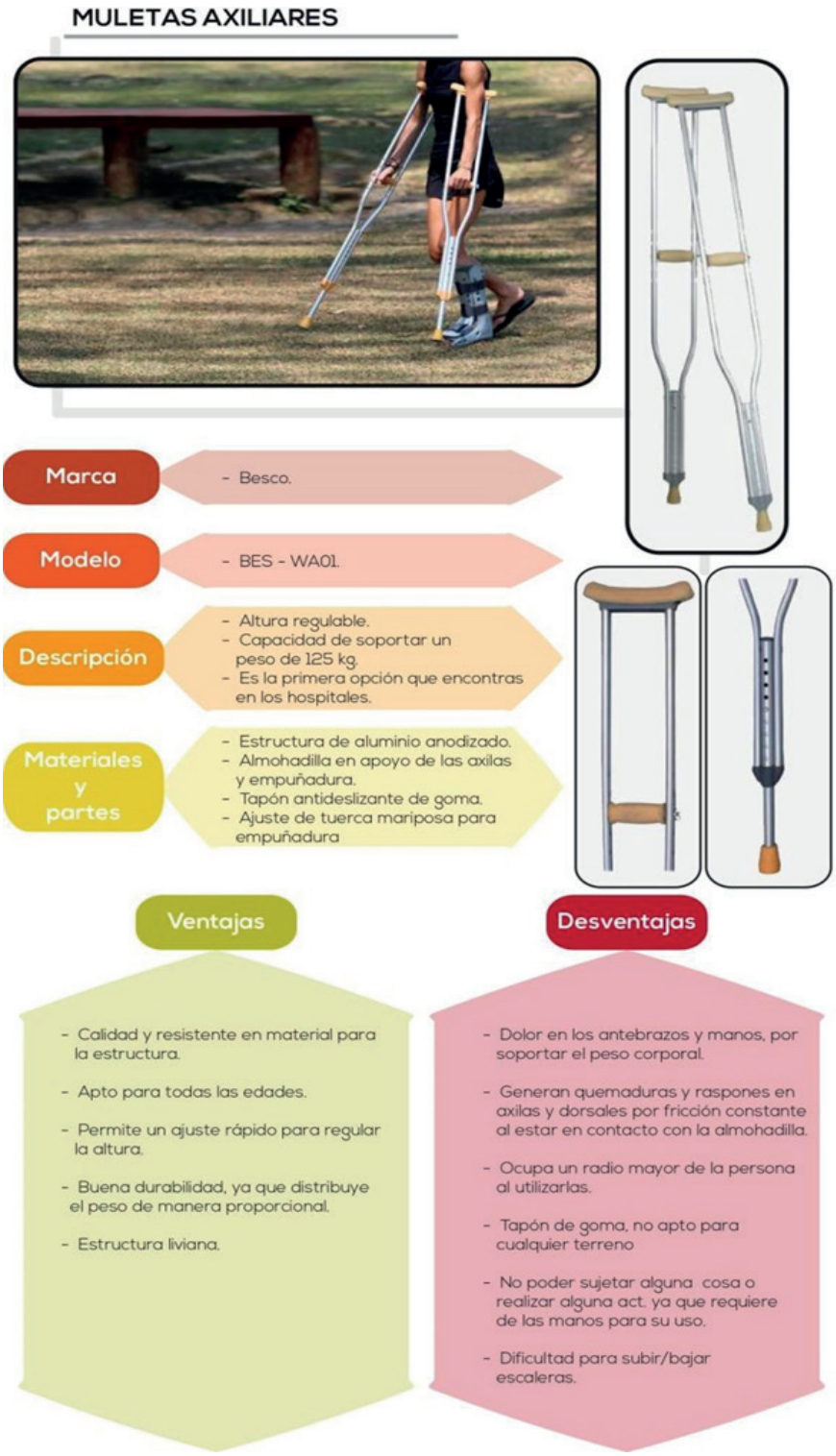
In conclusion, we can comment on what the former secretary of transportation explained in the personal interview, with which we totally agree. “If the state does not guarantee the right to mobility, it is impossible for it to guarantee other rights such as access to health, education, leisure, etc.” Therefore, in the next stage, we will conduct an in-depth analysis of the background, necessary qualities, and a concept in line with our problem, and then create an industrial design proposal for a body support element that is effective and

efficient, so that we can guarantee these people a better quality of life and the right to mobility, accessibility, leisure, among others.

Background

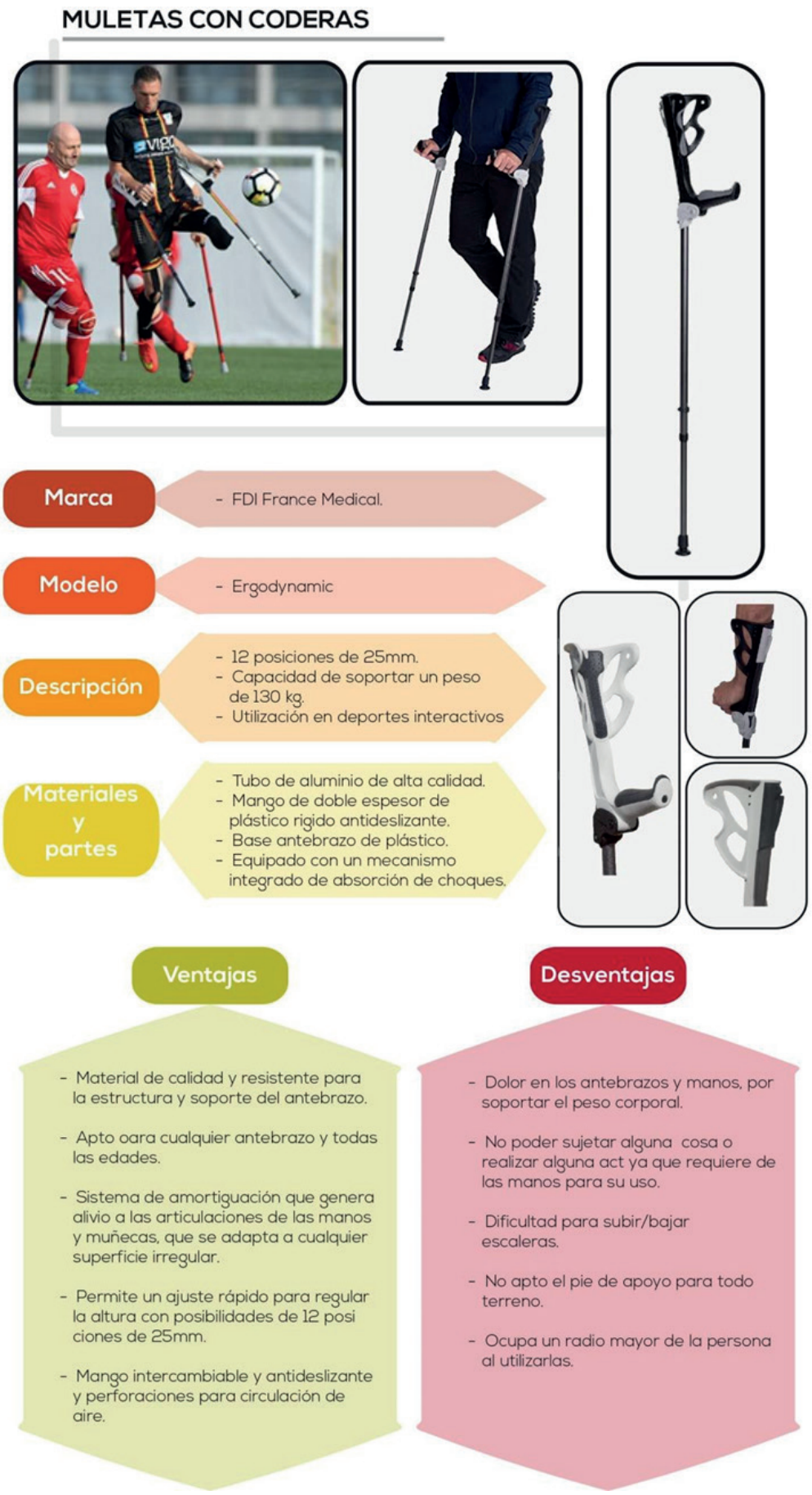
In this section, we will focus on background analysis, on the one hand, direct, that is, on products directly related to the problem at hand. Based on what was obtained in the data collection, we focused on the background of crutches, which facilitate the movement of people who have difficulty walking after an operation or accident. On the other hand, we will focus on indirect background information, i.e., products that have similar qualities or characteristics to the problem at hand.

In the following figures, we will detail the products that are directly related to the problem.

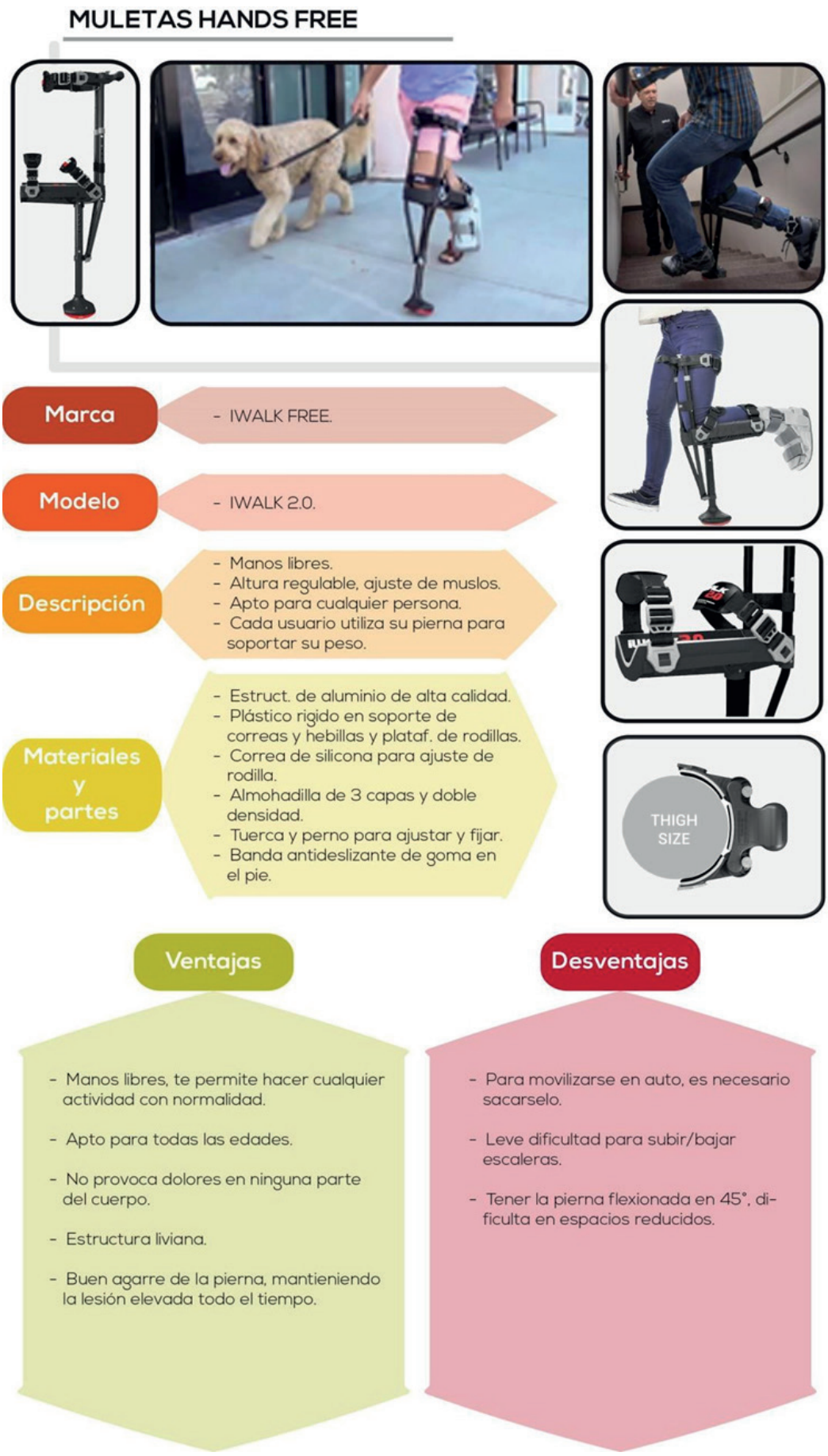


Source: data obtained from the brand (https://bit.ly/2LzpPFc)

Figure 6. Direct background 1

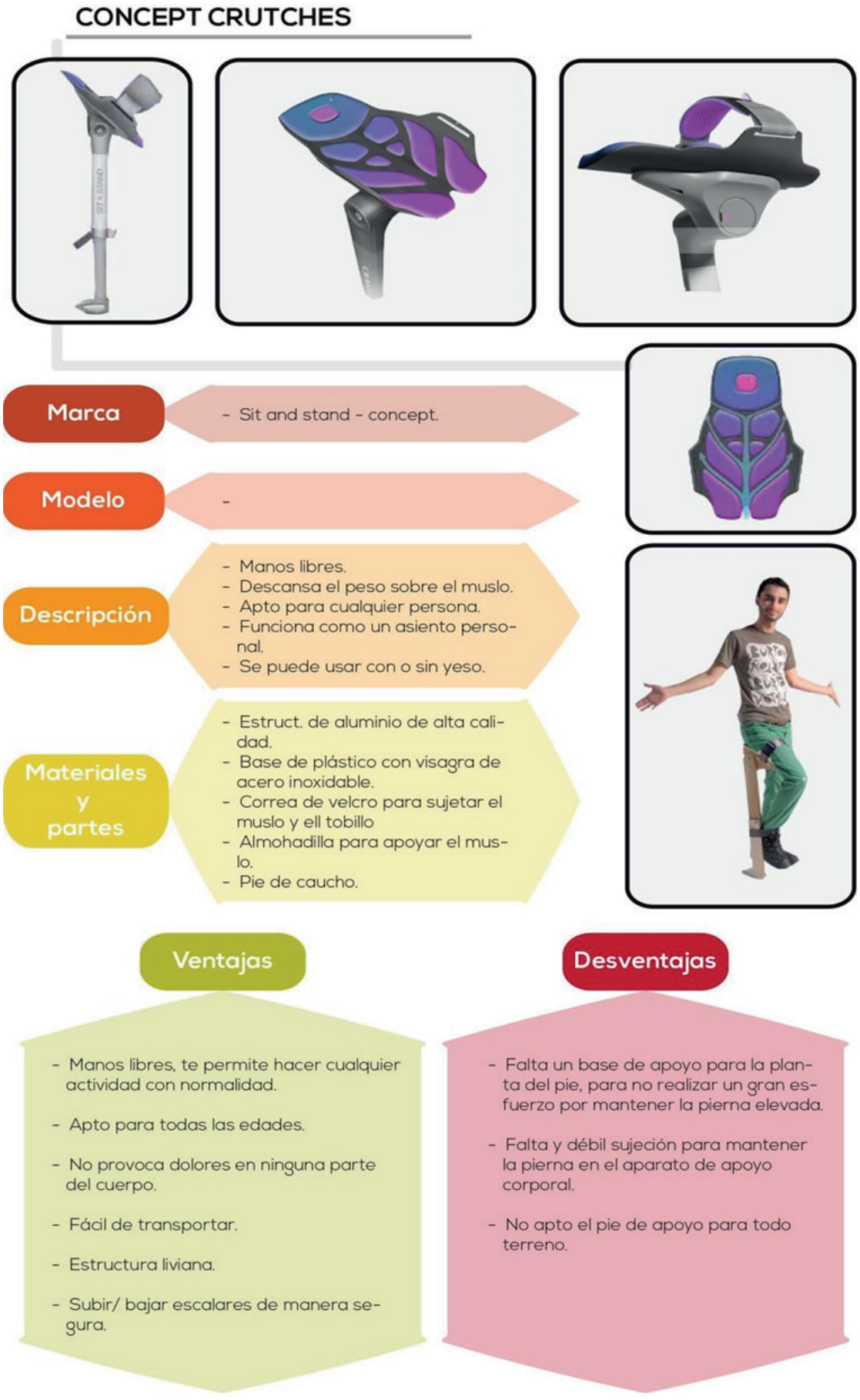


Source: data obtained from the brand (https://bit.ly/2WCOAXu)
Figure 7. Direct background 2



Source: data obtained from the brand (https://bit.ly/2WYRZ1S)
Figure 8. Direct antecedent 3

Source: data obtained from the brand (https://bit.ly/3dWa3jT)
Figure 9. Direct antecedent 4



Source: data obtained from the brand (https://bit.ly/3g87sFN)

Figure 10. Direct antecedent 5

Source: data obtained from the brand (https://bit.ly/3bIZdfT)

Figure 11. Direct antecedent 6

In the following figures, we will specify the products that have an indirect relationship with the problem.

SILLA PORTABLE

Marca
- Chairless chair

¿Qué es?
- Exo-esqueleto flexible que permite a las personas tomar asiento donde, y cuando lo desean.

Descripciones destacadas
- Moverse con total libertad.
- Posibilidad de adoptar una posición fija. En este caso es sentarse.
- Exoesqueleto parcial de cintura para abajo.
- Las patas se mueven con uno mismo.
- No estorban el movimiento corporal.
- Personalizable para diferentes tamaños de cuerpo y calzado de seguridad.

Figure 12. Indirect antecedent 1

NEUMÁTICO SIN AIRE

¿Qué es?
- Neumáticos innovadores sin aire.

Marca
- Michellin.

Material
Resina insertada en fibra de carbono.

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Figure 13. Indirect antecedent 2

Figure 14. Indirect antecedent 3

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Work plan

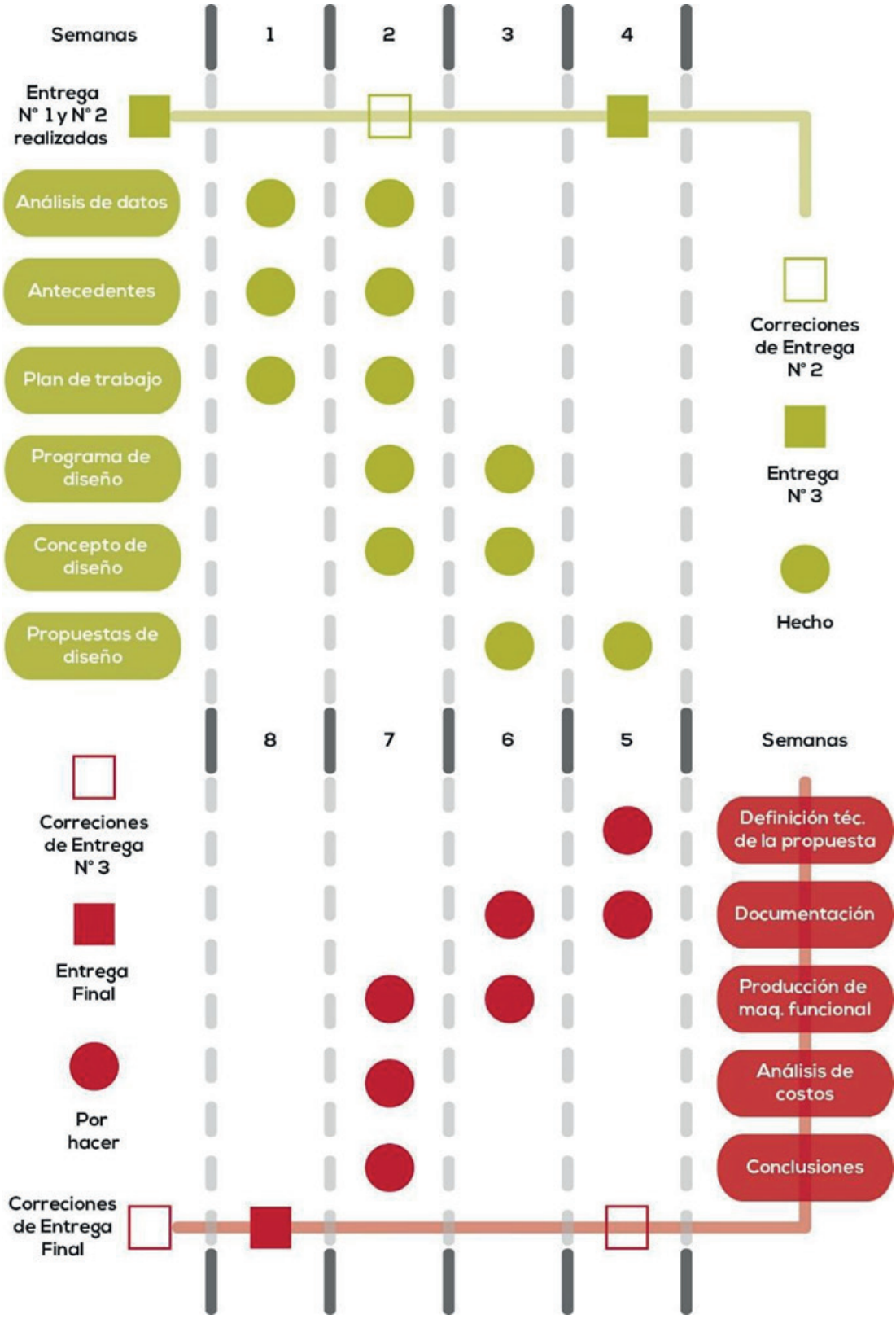

Figure 15. Work plan

RESULTS

Design program

Below, we will detail the design program, which was developed in order to organize the priorities and qualities required by this research to achieve a feasible solution.

SUJETO

USUARIO

- Persona entre 15 a 45 años sin distinción de género.
- Personas que practican un deporte y requieren una rápida recuperación.
- Personas que han sido operados o tienen algún tipo de lesión en la pierna como:
  - Rotura de Ligamentos Cruzado Anterior.
  - Meñiscos.
- Peso máx del usuario: 120 kg.

NECESIDAD

- Sentirse tolerante al usar el artefacto ortopédico.
- No interferir en el uso de otras partes del cuerpo, como las manos, para el uso adecuado del objeto.
- Subir y bajar escaleras, superar obstáculos, de manera estable y segura.
- El objeto de apoyo corporal genere la sensación que es parte del cuerpo humano.
- Realizar la mayor cant. de actividades sin ningún problema.
- Superar cualquier barrera física urbana o mobiliaria que se presente en su desplazamiento.

REQUERIMIENTO

- Evitar daños o esfuerzos físicos en la lesión o en alguna otra parte del cuerpo por parte del usuario.
- Adecuada relación producto-usuario en cuanto a su biomecánica
- Transmitir al cliente calidad y fiabilidad en ventas, producción y uso del producto.

PERCENTIL

- Utilizar percentiles de partes de la pierna adecuados en relación a las dimensiones entre el producto y el usuario.

		PESO	RODILLA(A)	POPLITEA (B)	INGLE (C)
		kg	cm	cm	cm
95	HOMBRES	97,7	60,3	47,8	91,9
	MUJERES	74,9	54,3	44,2	81,3
5	HOMBRES	65,2	52,1	40,4	78,2
	MUJERES	47,4	46,7	37,8	68,1

Dimensiones de rodilla, poplitea e ingle de hombres y mujeres adultos, en centímetros, según edad, peso y selección de percentiles

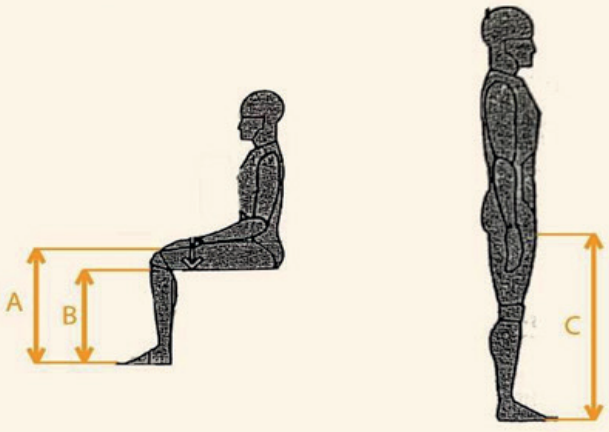

Figure 16. Subject

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PRODUCTO

RENDIMIENTO

- Cumplirá con la comodidad y calidad de vida que el usuario esta buscando, es decir, no generará consecuencias al utilizar el producto.
- Deberá ser práctico y transmitir una adecuada percepción en como se usa.
- El mayor alcance de la vida del producto que pueda tener en un centro de rehabilitación u hospital, permitiendo un uso constante por diferentes personas.

TECNOLOGÍA

- Plástico ABS y aluminio de alta calidad para la estructura general y componentes de apoyo. Moldeo por inyección en plástico y moldeo por extrusión en aluminio y trat .anodizado.
- Correas de fibras sinteticas de poliester y velcro para sujeción. Máquina de coser
- Almohadillas y siliconas para una mejor amortiguación.
- Santoprene para el pie de apoyo.

TERMINACIONES

- Acabado superficial liso con líneas y texturas suaves.
- Tamaño adecuado con una estructura liviana que genere que es una parte más del cuerpo.
- Se utilizarán colores como el negro y el azul, transmitiendo fiabilidad, sotisficación y calidad ya que estos colores tienen vinculación con la tecnología y salud.

ERGONOMÍA

- Generar comodidad y practicidad en la colocación y manipulación para el uso.
- Adaptable a diferentes medidas de muslo, pantorilla, rodilla y tobillo de las personas.
- Indicadores de uso en cada componente que requiera manipulación por parte del usuario.

ESPECIFICACIONES TÉCNICAS

- Peso máx del producto: 900 gramos.
- Tamaño regulable de acuerdo a las medidas antropométricas del usuario.
- Requerirá de un manual para el usuario para la instalación.
- El producto y sus componentes se desmontarán a futuro a efecto de eliminación o de reciclado.

EMBALAJE Y MANTENIMIENTO

- Cartón reciclado para envoltorio externo.
- Implementarán materiales reciclables dentro de la caja para prevenir golpes y evitar daños del artefacto .
- Logo de la marca se verá claramente en el embalaje.
- La sustitución y limpieza de componentes será fácil de realizar y al alcance del usuario.
- El producto deberá ir acompañado de la documentación completa de su uso y mantenimiento requerido.

PRECIO DEL PRODUCTO Y CANTIDAD

- El precio de venta será de $15.000.
- Se realizará un prototipo funcional.
- Si es factible, se hará un análisis de alcance productivo y almacenamiento.

Figure 17. Product

https://doi.org/10.56294/tms202241 ISSN: 3072-8398

Figure 18. Environment

Design concept

This section will guide the direction of the research until a solution to the problem is found. The aim is to correctly define the sensory, communicative, and morphological intentions of our research design. In this way, we will be able to create the meaning or "soul" of the product, which we want to express in our product and in the people it is aimed at, so that it performs satisfactorily in its environment of use. In the following figure, we will distinguish the impact that the subject has on urban environments when using crutches today, and what we really want to achieve and fulfill for our future industrial design product.

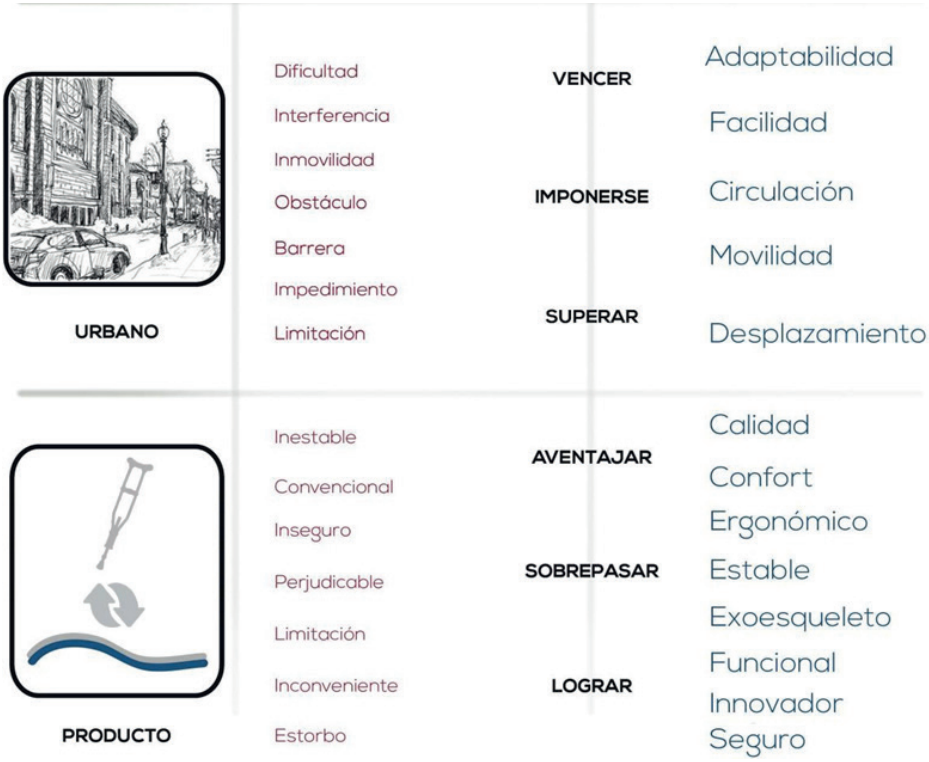

Figure 19. Design concept

Based on the above summary, important words and phrases were highlighted and will be expressed in the next figure, which will guide us in selecting the concept.

Figure 20. Design concept

With regard to the selection of colors, we opted for the range of blues, grays, whites, and blacks as they represent wisdom, quality, unity, stability, sophistication, and reliability. In relation to marketing, these colors are appropriate as our product is focused on technology and health, in which we want to convey confidence, responsibility, and precision.

Based on the selection of the concept, INDEPENDENT MOBILITY, we defined it as the most appropriate concept for our body support product. It is the most appropriate in our selection, as we want to ensure that users, both young and adult, have the greatest possible independence in their mobility and in carrying out their activities.

Design alternatives

In this important design stage, we will look at three design alternatives that were generated from the information gathered and the design program that was established for the development of the product. Unfortunately, alternatives No. 1 and No. 2 have been ruled out because we have observed that the creation of several molds for the manufacture and injection of parts presents a certain complexity in terms of development. In the following figures, we can observe the development of each of the alternatives.

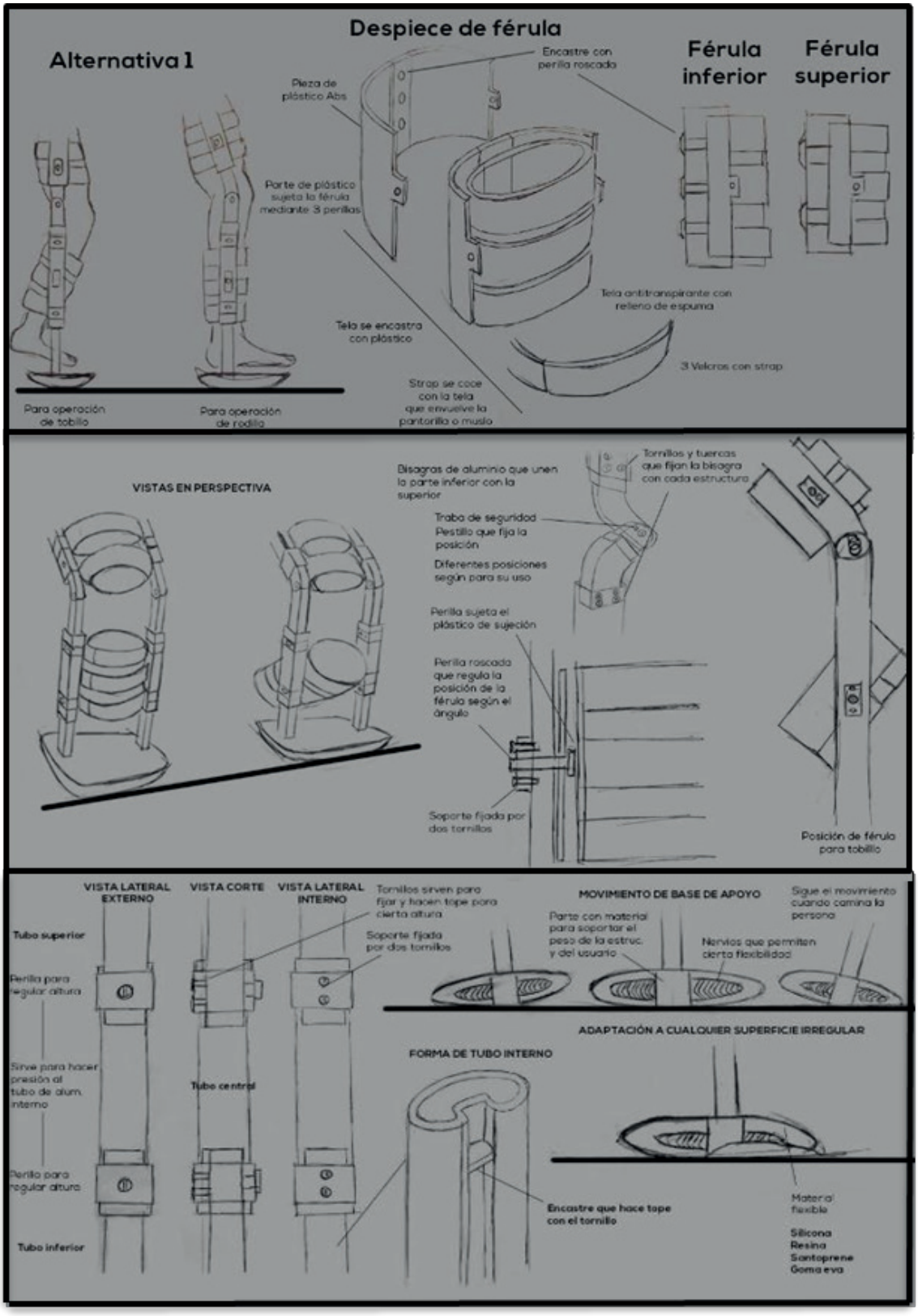

Figure 21. Alternative 1

Figure 22. Alternative No. 1

Alternative No. 1 targets a broad potential audience, which makes it difficult to adapt the product to such a large number of potential users.

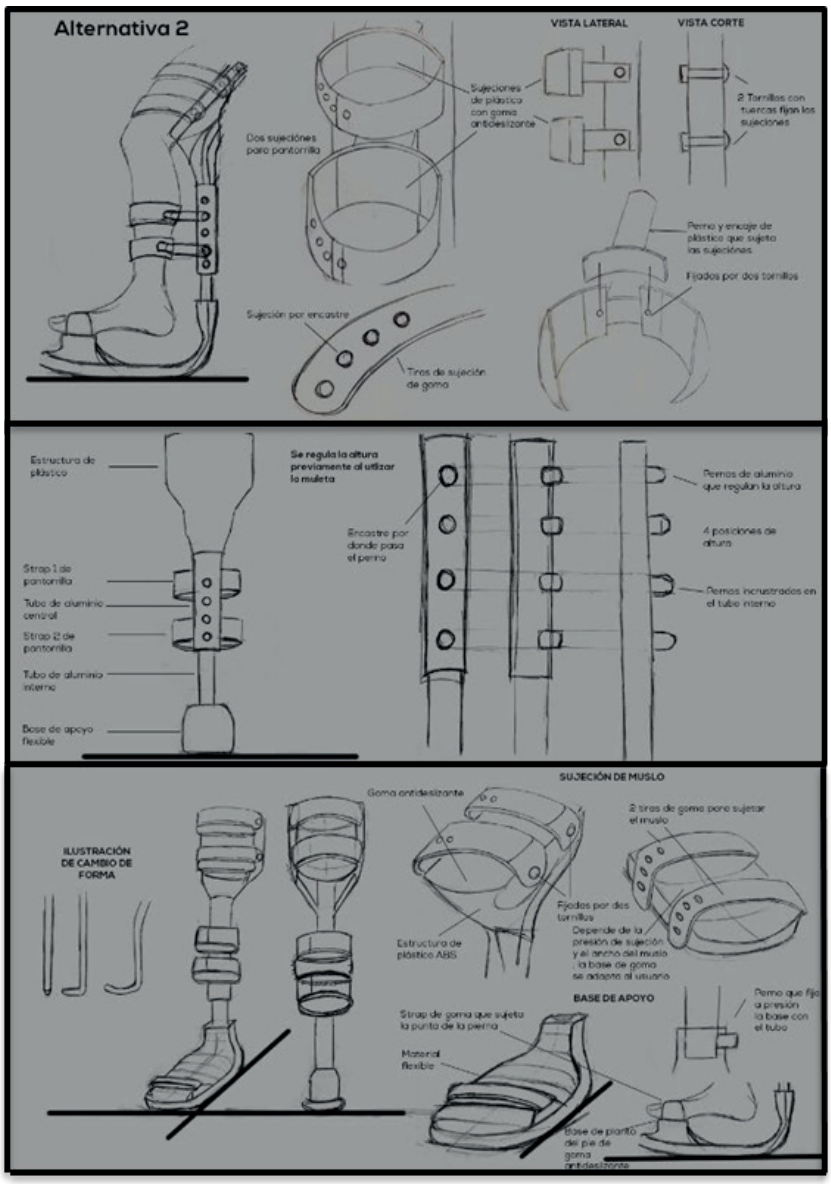

Figure 23. Alternative 2

Figure 24. Alternative 2

With regard to alternative No. 2, the level of comfort sought is not within the user's expectations.

However, these drawbacks proved favorable to us, as we were able to develop a different proposal, draw conclusions, and identify relevant qualities to implement in the chosen alternative.

Technical definition of the proposal

Final design proposal (Alternative No. 3)

Figure 25. Final proposal

https://doi.org/10.56294/tms202241 ISSN: 3072-8398

In this section, we will define different aspects of the selection of an alternative that stood out above the others. Our objective was always for the final proposal for our industrial design product to offer maximum comfort in functional, aesthetic, and morphological terms and to provide the greatest possible independence for the user's daily mobility. In the following figures, we can see the achievements we desired for our final proposal.

Product use and environment

Figure 26. Adaptable to uneven surfaces

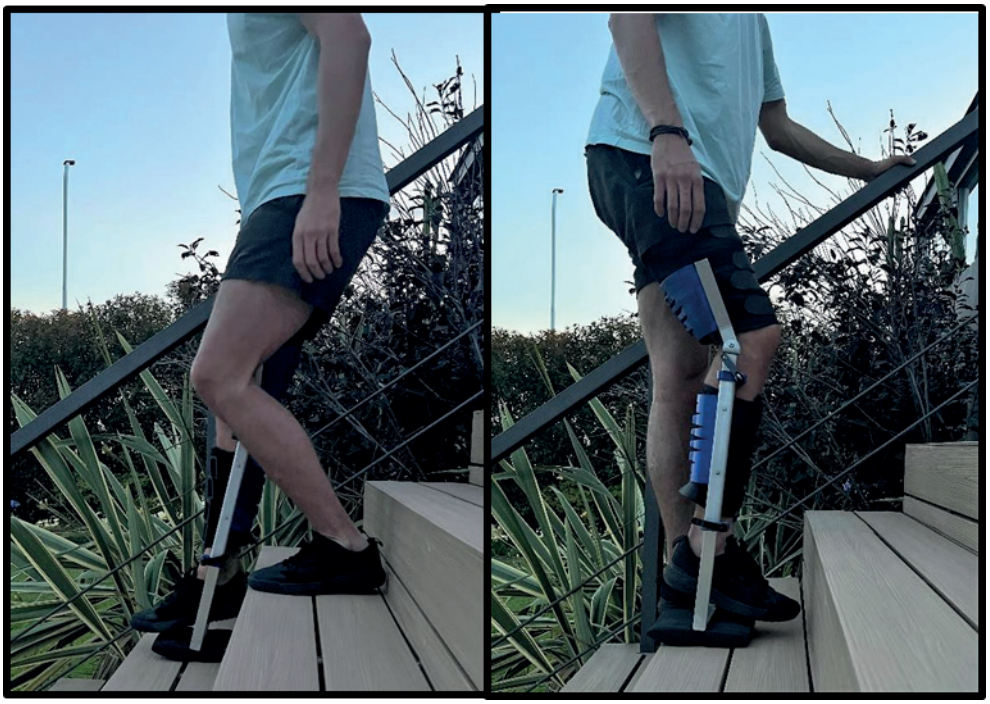

Figure 27. Use on stairs

Figure 28. Sitting position

Technical specifications of product parts

Components of the proposal

Below, we will illustrate all the components of our industrial design product, which will guide us throughout the development process.

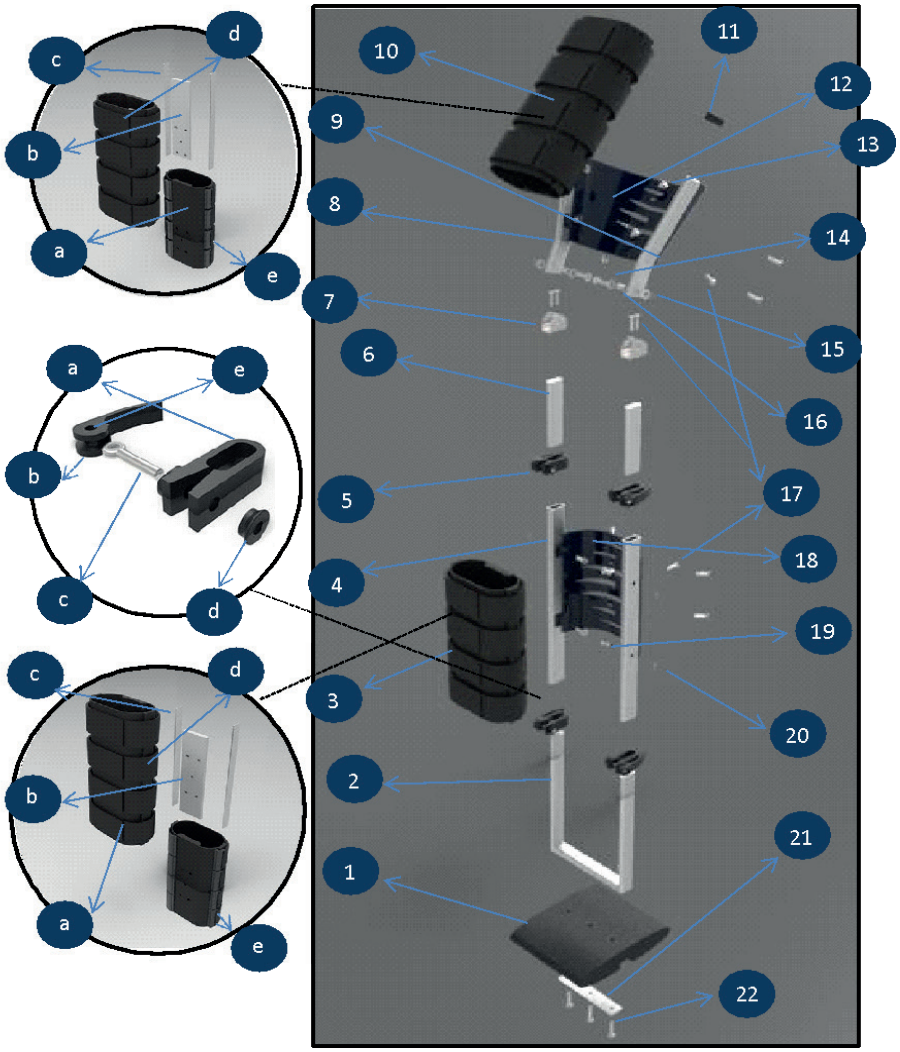

Figure 29. Alternative components

1. Support base. Extruded Santoprene.
2. Lower foot. Extruded 6061 aluminum.
3. Calf strap.
    a. Splint. Neoprene fabric and polyester brin.
    b. Support fastening. Extruded and machined 6061 aluminum.
    c. Rod. Quantity: 2. 6061 aluminum.
    d. Elastic Velcro straps. Polyester fibers.
    e. Buckles. ABS plastic.

4. Central tube. Quantity: 2. Extruded and machined 6061 aluminum.
5. Height adjustment. Quantity: 4
    a. Tube clamp. Extruded 6061 aluminum with RAL 5013 blue additives.
    b. Handle. Extruded and machined 6061 aluminum.
    c. Nut with internal thread. Extruded and machined 6061 aluminum.
    d. Threaded through bolt. 6061 aluminum.
    e. Internal bolt. 1045 steel.

6. Lower bar. Quantity: 2. Extruded and machined 6061 aluminum.
7. U-joint. Quantity: 2. SAE 1045 steel, extruded and machined. RAL 9007 color additives.
8. Upper right bar with bend. Quantity: 1. Extruded and machined 6061 aluminum.
9. Upper left bar with bend. Quantity: 1. Extruded and machined 6061 aluminum.
10. Thigh strap.
    a. Splint. Neoprene fabric and polyester brin.
    b. Support fastening. Extruded and machined 6061 aluminum.
    c. Rod. Quantity: 2. 6061 aluminum.
    d. Velcro straps with elastic. Polyester fibers.
    e. Buckles. ABS plastic.

11. Cap. Quantity: 2. Extruded Santoprene.
12. Thigh protection. Injection-molded ABS plastic with RAL 5013 blue additives.
13. Countersunk screw M6X10mm. Quantity: 4
14. M6X20mm button head screw. Quantity: 2
15. M8 flat washer with internal thread. Quantity: 4
16. Bushing. Quantity: 2. SAE 1045 steel.
17. M5X20mm countersunk head screw. Quantity: 14
18. Shin guard. Injection-molded ABS plastic with RAL 5013 blue additives.
19. M6X15mm countersunk head screw. Quantity: 4.
20. M6 grower washer. Quantity: 8.
21. Grip plate. Aluminum 6061.
22. M6x30mm countersunk head screw. Quantity: 3

Once all the components are ready, proceed with the final assembly, joining all the pieces with screws and washers in their respective places.

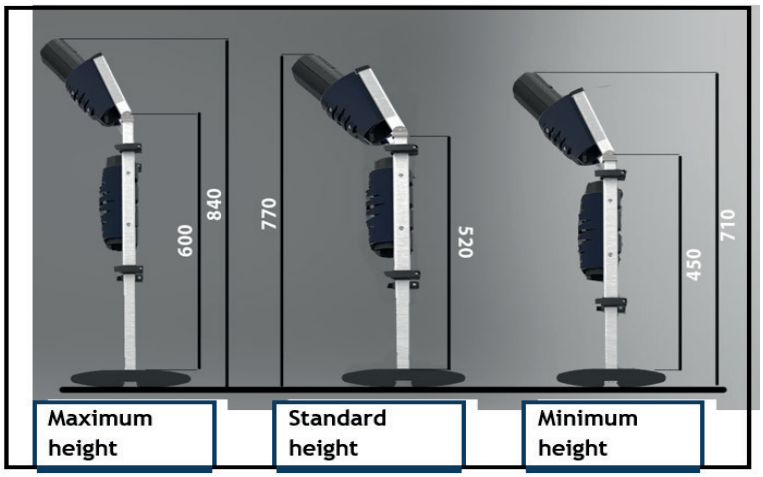

Figure 30. Crutch heights

One of our design intentions is for the orthopedic crutch to be used by a person who is actively involved in sports and needs to recover as quickly as possible to return to their routine. Therefore, our target user range is between 15 and 45 years old, because, first of all, the development and growth of the leg show similar anthropometric measurements in the adolescent-adult ages. In addition, the specified age range is the largest percentage in which people tend to fracture or weaken due to blows, injuries, or muscle overload. Thus, taking as a reference the percentiles of people from the ankle to the knee, we have made the crutch adjustable to different height levels so that it can be used by people between 1,50 and 1,95 meters tall.

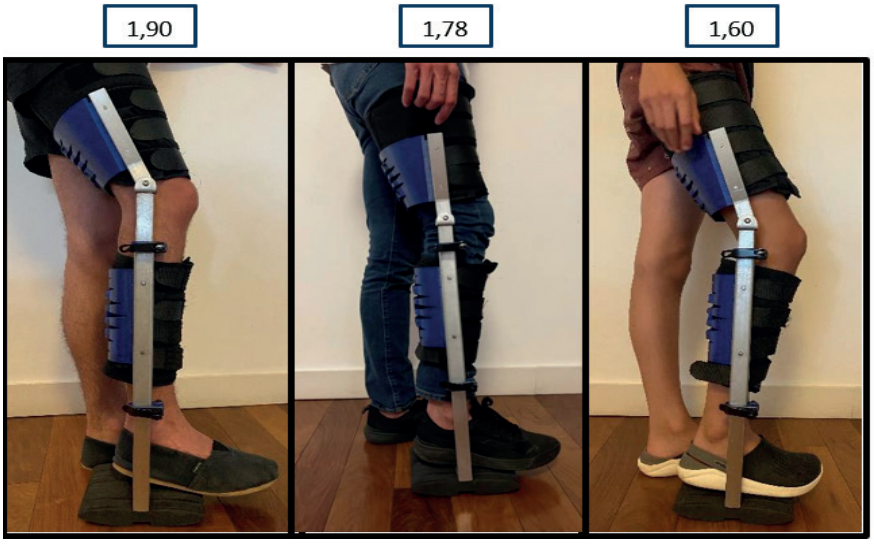

Figure 31. Model in use for users of different heights (meters)

This is achieved by means of four clamps (5) that grip and apply pressure to the lower bars (6) and the upper ends of the lower foot (2). This pressure can be adjusted by the user to suit their own needs and height. Two of them are located at the bottom of the central tube (4), where they regulate the height from the ankle to the central structure of the crutch, and the other is located at the top of the central tube, regulating the height from the knee to the central structure of the device. Below, we can see how this works.

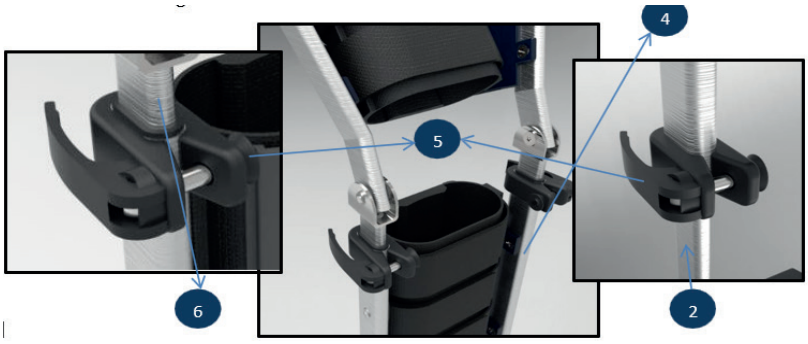

Figure 32. Height adjustment

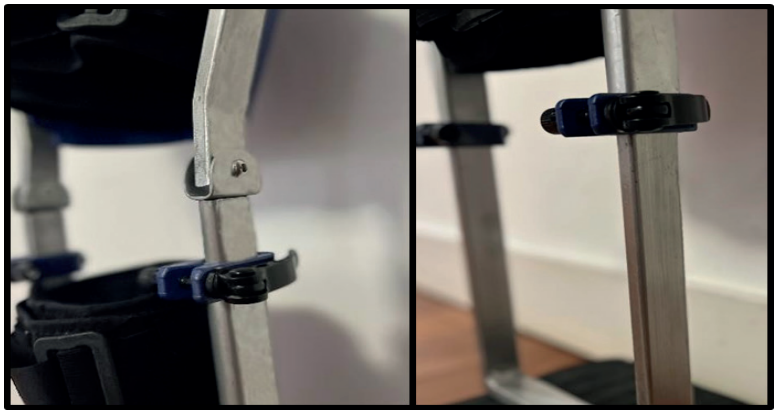

Figure 33. Model with detailed view of height adjustment

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With regard to the joints, the orthopedic crutch is divided into two main areas. On one side, there is the calf support (3) with its protection (18) and the lower foot (2) with the support base (1), and on the other side, there is the thigh support (11) with its protection (13). These two important parts are joined by a U-shaped steel plate on each side (7), and provide a bushing (16) with an internal thread and a through bolt that crosses each upper tube, allowing the device to move slightly (from 65° to 90°) when walking or sitting. This movement is limited by a steel piece welded to the bottom of the U-shaped piece, preventing the user from bending their leg. Finally, to connect the two large parts, the U-shaped plate is attached to the respective lower bars with screws. The following figure illustrates this.

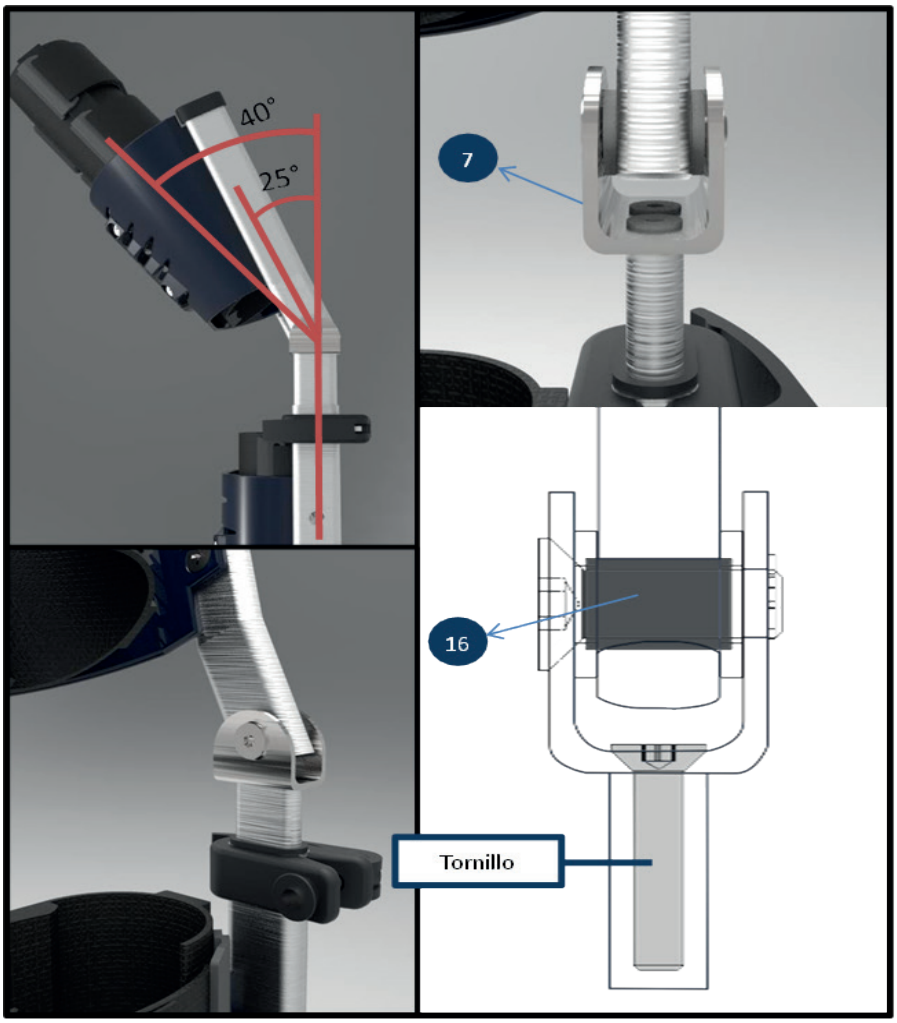

Figure 34. U-shaped plate

Figure 35. Calf support with protection

With regard to the crutch's adaptation to users between 15 and 45 years of age, the splint system with polyester straps and Velcro fasteners fits comfortably on smaller/larger calves and thighs (even when wearing a cast), as each Velcro fastener has a sewn-in elastic band. The adjustment is made when each polyester strap is passed through the corresponding buckle, adjusting it as much as possible, and then attaching the strap to the Velcro.

Figure 36. Thigh support with protection

The opening and closing measurements of the calf splint are a minimum of 36 cm and a maximum of 44 cm. The minimum measurement for the thigh splint is 46 cm and the maximum is 60 cm. The following figures illustrate this.

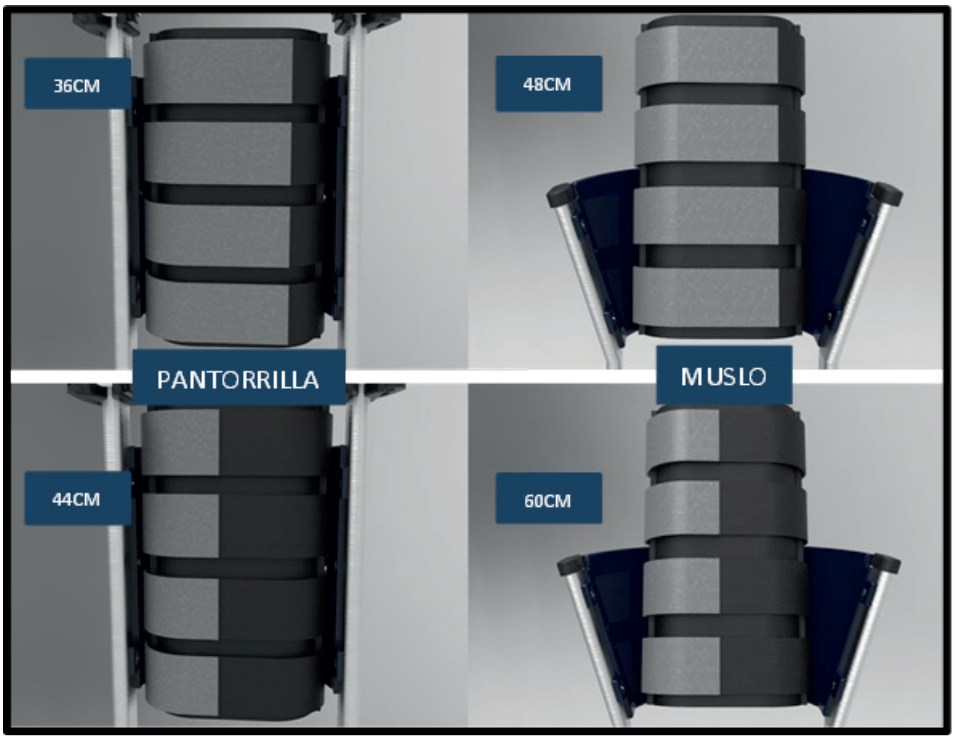

Figure 37. Detailed view of splint measurements

The calf (3) and thigh (10) are secured with the protection (12/18) using five screws each, one in the center and two on each side to hold them firmly in place. The position of the screws allows the splints to remain centered when the user places them on each part of the leg, allowing the subject to walk comfortably and safely.

Figure 38. Detailed view of thigh/calf protection

The calf and thigh support fastenings are located at the rear of each splint. They are sewn onto the outer contour with thread to keep the piece in place. The following figures provide further details on all of the above.

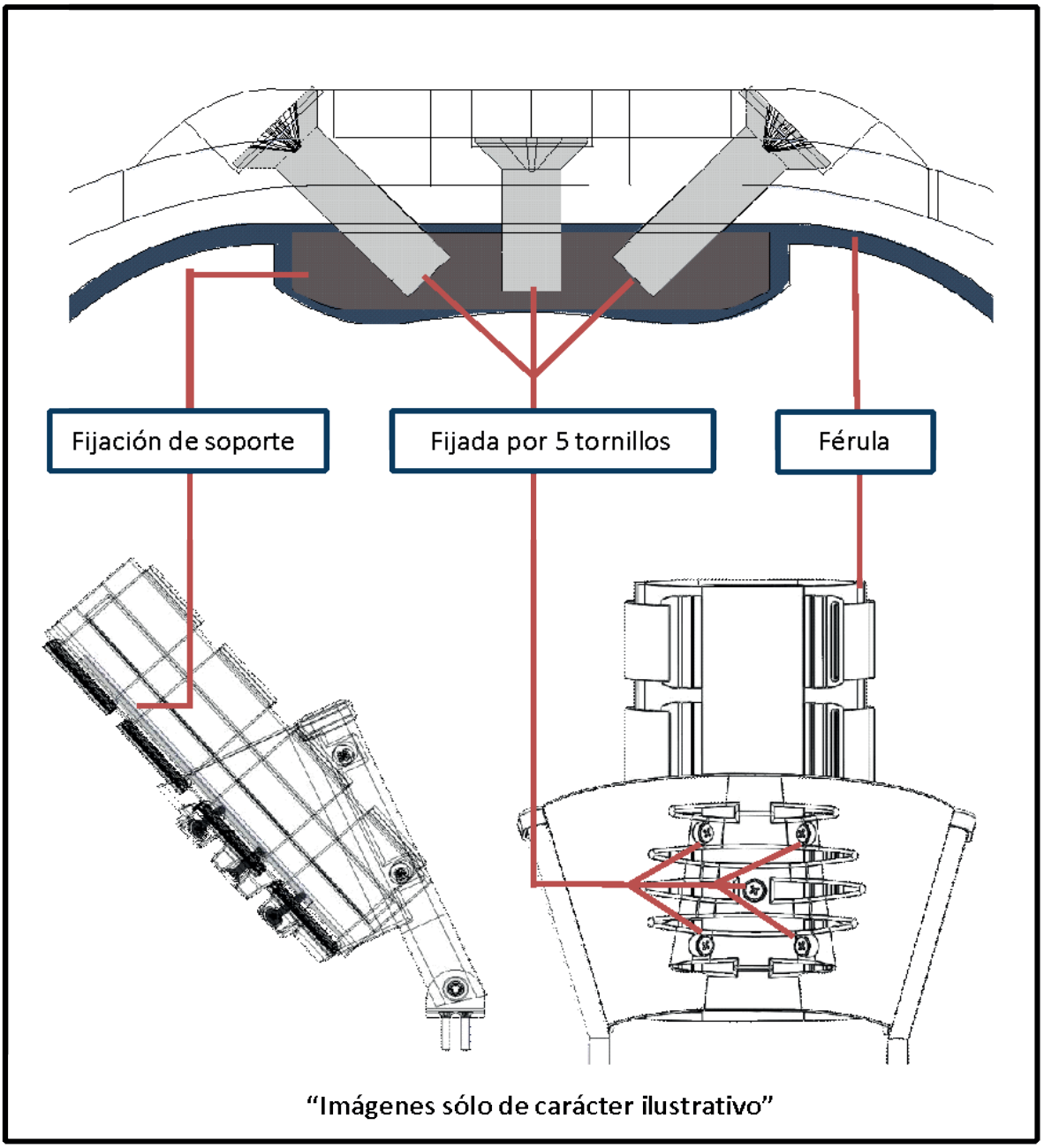

Figure 39. Splint fastening with calf/thigh protection

In addition, the support base (1) was designed to be adaptable to any uneven surface, so that the user does not have to worry about overcoming different urban obstacles when going out into the urban environment. Therefore, it was studied and analyzed that a base made of Santoprene material would be feasible, as it can mold to different terrains. The base was also designed to have a specific angle at its ends, so that it accompanies the movement made by the person when walking.

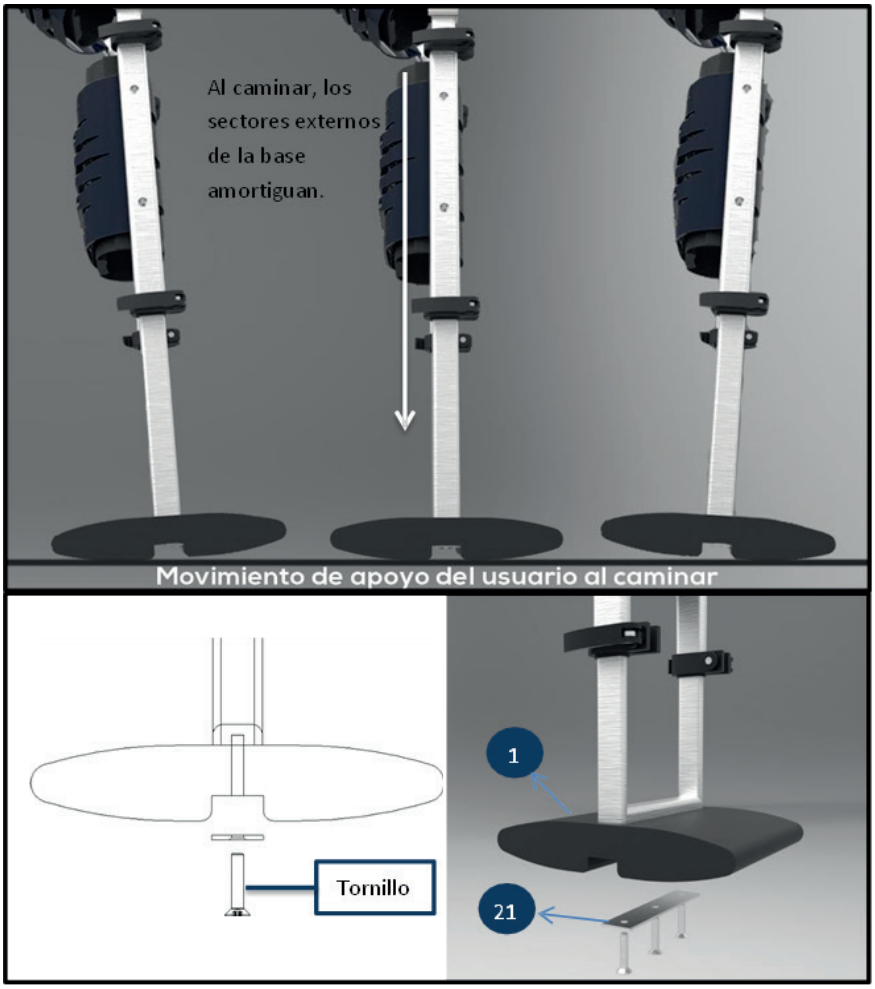

Figure 40. Support movement

The support base is attached to the aluminum structure by means of an aluminum grip plate (21) which is incorporated underneath the base by means of three screws.

Figure 41. Support base model

The following link shows the development of each component of the crutch. (https://drive.google.com/drive/folders/1zFG2tIlQXg34qpadR2u5R7P1qihXFXH2)

Figure 42. Final alternative model

Product assembly

With regard to the transportation of the industrial product, a compact modular design was developed using pre-selected recycled cardboard for the outer packaging. In addition, to ensure efficient and safe transportation, the product will be placed as snugly and compactly as possible so that the box has dimensions suitable for transport. The box design is done by us, with PET sheets on all sides of the box, and both the manufacturing of the box and the pressing of the recycled materials are outsourced. Finally, we want the crutch to be received by the customer without the need to manipulate the elements and components too much. Therefore, the customer will receive, along with the product, an M6 Allen key to perform the only adjustment operation, as can be seen in the following figure.

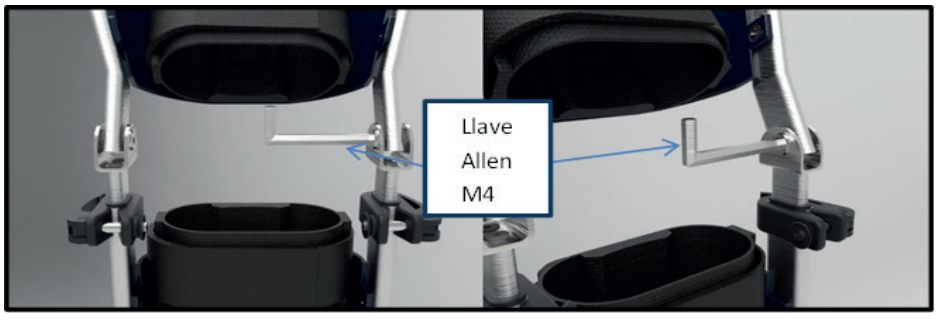

Figure 43. M6 Allen key for adjustment

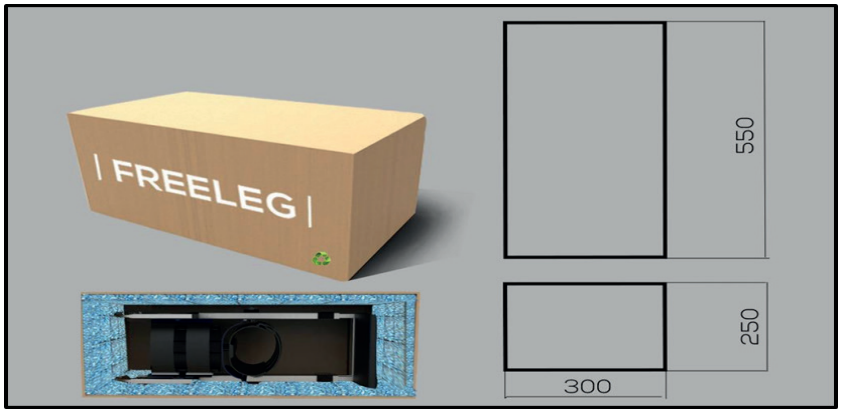

Figure 44. Box dimensions for transport

Cost analysis

To carry out this research efficiently, it is extremely important to take into account the costs generated throughout the industrial product's production process. First, we will show the materials that will be used to carry out the project and the cost per kg or meter of each one. Then, we will show all the costs involved in manufacturing one unit, and if the project is successful, we will provide a cost estimate of what we want to produce per month to give an overview of the future.

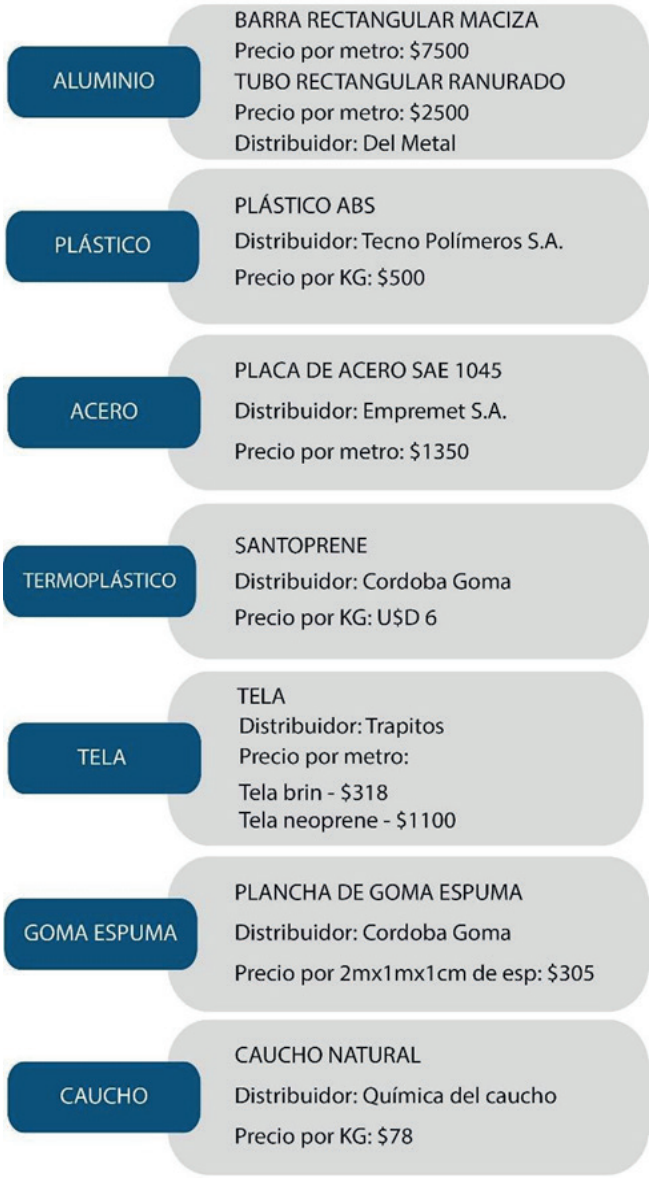

Figure 45. Materials and costs

Table 1. Costs per unit

Materials	Quantity	Cost
B. Rectangular aluminum	1400 mm x 25 mm x 10 mm	$10 500
Rectangular pipe	600 mm x 28 mm x 12 mm	$450
Abs plastic	290 grams	$145
B. Rectangular steel	70 mm x 65 mm x 20 mm	$44,33
Thermoplastic	928 grams	$835
Brin fabric	450 mm	$205
Neoprene fabric	450 mm	$650
Velcro with elastic	3600 mm	$840
Foam rubber	850 mm	$255
Rubber	35 grams	$33,25
Plastic buckles	8 units	$150
M6x10mm SCREWS	4 (1 bag of 50 pcs.)	$60
M6x20mm SCREWS	2 (1 bag of 50 units)	$750
M5x20mm SCREWS	14 (1 bag of 50 units)	$750
M6x15mm SCREWS	4 (1 bag of 50 units)	$70
M6x30mm SCREWS	3 (1 bag of 50 units)	$75
M6 grower washer	4 (1 bag of 50 units)	$150
Flat washer m8	4 (1 bag of 50 units)	$150
Box and packaging design	1 (550X300X250)	$320
Pet sheets	6 (550x300x250)	$550
Total cost	-	$18 827

Table 2. Costs per 50 units

Materials	Quantity	Cost
B. Rectangular aluminum	100 400 mm	$525 000
Rectangular pipe	30 000 mm	$22 500
Abs plastic	14 500 grams	$600
B. Rectangular steel	3500 mm	$2200
Thermoplastic	46,4kg	$41 750
Brin fabric	22 500 mm	$6500
Neoprene fabric	22 250 mm	$11 000
Velcro with elastic	18 000 mm	$4194
Foam rubber	42 500 mm	$2550
Rubber	1750 grams	$1662
Plastic buckles	400 units	$750
M6 x 10mm screws	200 units	$2400
M6 x 20mm screws	100 units	$1500
M5 x 20mm screws	700 units	$10 500
M6 x 15mm screws	200 units	$2800
M6 x 30mm screws	150 units	$2250
M6 grower washer	200 units	$600
Flat washer m8	200 units	$600
Box and packaging design	50 units.	$16,000
Pet sheets	50 units	$27 500
Total cost	-	$694 456

Based on the information obtained and taking into account all the costs involved in manufacturing the product, we will propose an estimated price for the product. To do this, we will use a simple formula in which

we will apply a 50 % profit margin to the cost of the product.

PRICE = $18 827 x (100/100-50)
PRICE = $18 827 X (100/50)
PRICE = $18 827 X 2

PRECIO= $37.654

Based on the result, the product could be sold at a price of $37 654, which would provide the user with independent and comfortable mobility that would not hinder their rehabilitation.

With regard to production, based on an estimate of 50 units per month, we could consider the project feasible, as we would cover the costs generated by the units manufactured and obtain profits from the guarantee we would have in marketing. The following table shows this.

Table 3. Total savings per month of production

Income	$
50 freeleg	1,882,700
Total income	1,882,700
Expenses	$
B. Rectangular aluminum	326,300
Rectangular pipe	9,000
Abs plastic	600
B. Rectangular steel	2200
Thermoplastic	41750
Brin fabric	650
Neoprene fabric	11,000
Velcro with elastic	4194
Foam rubber	2550
Rubber	1662
Plastic buckles	7500
M6 X 10mm SCREWS	2400
M6 X 20mm SCREWS	1500
M5 X 20mm SCREWS	10,500
M6 X 15mm SCREWS	2800
M6 X 30mm SCREWS	2250
Grower washer m6	600
Flat washer m8	600
Box and design of	16,000
Packaging design	
Pet sheets	27,050
Total expenses	694,456
Total savings	1,813,254

In any case, it was found that the estimated price was higher than that of other competing products. However, this allows us to distinguish ourselves through the quality and safety offered by the industrial product, positioning us in a premium category. Furthermore, we concluded that potential customers would be rehabilitation centers and hospitals, which would purchase the product and then rent the orthopedic device to post-operative patients, as it is generally for temporary use.

CONCLUSIONS

At the beginning of this research, we decided to focus on the topic of personal urban mobility design because

we believe it is important to provide a solution for the mobility of people with certain motor impairments in urban environments, which would positively change their routine and improve their quality of life.

In order to carry out the research, certain objectives were defined to be met throughout the project, such as examining and classifying the problems caused by these physical and emotional urban barriers for people with reduced mobility, and then studying and investigating the anthropometric measurements of body support elements. Based on this, a viable solution for body support for people with physical disabilities was created, with the possibility of improving their mobility and even their post-operative recovery.

This work is mainly based on the difficulties and consequences that people with certain physical disabilities face in their daily mobility, which affects them both physically and emotionally. This is because an analysis was carried out on people who are exposed to this problem and who must fight for a better quality of life.

From this, the goal was set to collaborate through an industrial design product that would overcome these physical barriers and emotional consequences, thereby achieving a desirable quality of life.

To explore this issue further, it was noted that today there is no consideration given when designing the urban environment, pedestrian paths, or appropriate infrastructure to include all the people who live in the city of Córdoba. All of this creates various physical inconveniences, undue effort, affects work performance, and causes negative emotions. For this reason, there are organizations that seek to raise awareness about inclusion in the government and urban development companies to reduce these consequences.

Once the objectives were defined, we wanted to delve deeper and verify that what we had investigated was within the scope of our research. Therefore, we sought to understand the behaviors and emotions experienced by these individuals when walking, and whether there were reasons why traveling around the city had an impact on their daily lives. To this end, a general survey was conducted among people in the city of Córdoba, in which the majority responded that they encountered certain limitations when moving around urban environments. In addition, this survey gave us a guideline on where to go, as during the research we found that there are countless elements that help people with lower limb immobility. To this end, we decided that, based on one of the questions in the general survey, the answer that obtained the highest percentage in that question would specify the type of person with walking ability and body support element we would focus on.

Once we obtained that answer, we wanted to delve deeper into the data through personal interviews with people who had or had had this lower motor difficulty, in which they gave us more in-depth information about situations they had faced, negative attitudes, and constructive opinions they had or had had in their routine, such as the fact that the sizes of the competition's post-operative orthopedic devices have a certain limitation in terms of comfortable movement in urban physical environments. On the other hand, we consulted with various external sources, such as physical therapists and the undersecretary of transportation, who provided us with essential information for our research.

Once all this data had been collected and analyzed, we studied and highlighted important characteristics of products directly related to the issue, and of orthopedic devices for people with lower limb motor impairments, i.e., crutches themselves. We were also able to identify qualities of indirect products that would help us with our project.

Subsequently, the design of the chosen alternative was developed in greater depth, prioritizing independence and comfort, and making it as easy as possible to handle and use. In addition, this crutch, which breaks with convention, is designed to give the user the possibility of completely improving their mobility, making the product part of themselves and allowing for better post-operative recovery.

The product design is an orthopedic crutch that allows the user to interact, perform routine and work activities, and, importantly, have their hands free. However, we conclude that potential customers would be rehabilitation centers and hospitals. They would make the purchase because the orthopedic device is for temporary use, and generally, people with ambulatory capacity rent a certain device to achieve better mobility.

In conclusion, with reference to our overall objective, we can affirm that the product that was developed fulfills the proposed purpose. However, this study was somewhat complex, as it required a great deal of focus on research for the development and precision of the components and processes. This meant that it was not possible to expand the range of users, on the one hand, to other lower limb disabilities, and on the other hand, to other age groups, as children do not have the same anthropometric measurements as adolescents and adults. In addition, certain regulations and tenders are required because it is a sophisticated product, which can limit its development. Therefore, it is proposed that in the future it would be challenging to have a group of people focused on product design to achieve and deepen better development in terms of quality, process, and production, achieving even greater objectives than those that were thought of or could have been taken into account throughout the project.

As future industrial design professionals, we must commit ourselves to investigating issues that involve meeting people's needs in the pursuit of well-being and quality of life. To do this, we must be attentive and aware that a need can always arise in any area of the world. This can be achieved by having the appropriate knowledge to meet the need being addressed and by having a clear and constructive perspective for product development.

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None.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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