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ORIGINAL

Design of a rehabilitation device for athletes with acute knee sprains in a soccer academy

Diseño de un dispositivo de rehabilitación para atletas con esguinces agudos de rodilla en una academia de fútbol

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ABSTRACT

Introduction: this study addresses the design of a rehabilitation device for athletes suffering from acute knee sprains within soccer academies. Knee injuries are among the most prevalent in sports, significantly impacting athletic performance and requiring effective rehabilitation solutions. Traditional rehabilitation approaches often lack accessibility and customization, prompting the development of innovative devices that align with athletes' specific needs.
Method: a mixed-method approach was employed, integrating qualitative and quantitative analyses. Data collection included interviews with physiotherapists and athletes, complemented by field observations in soccer academies. The design process combined User-Centered Design (UCD) and TRIZ methodologies to identify and resolve contradictions, leading to an optimal solution. Tools such as CAD software and rapid prototyping techniques facilitated the development of the device.
Results: the resulting device demonstrated effectiveness in aiding recovery from acute knee sprains. Athletes reported reduced pain, improved mobility, and shorter recovery times. Quantitative metrics, such as muscle strength and joint stability, indicated significant improvements, while qualitative feedback highlighted the device's comfort and user-friendliness.
Conclusions: the rehabilitation device represents a novel contribution to sports medicine, particularly for soccer academies. Its innovative design addresses the specific requirements of athletes, enhancing their recovery process and performance. Despite its potential, further studies are needed to validate its efficacy across broader populations and diverse sports disciplines. This research underscores the importance of integrating design, technology, and medical expertise to develop impactful rehabilitation solutions.

Keywords: Industrial Design; Design; Materials; Rehabilitation Devices.

RESUMEN

Introducción: este estudio aborda el diseño de un dispositivo de rehabilitación para atletas que sufren esguinces agudos de rodilla en academias de fútbol. Las lesiones de rodilla están entre las más frecuentes en el deporte, impactando significativamente el rendimiento atlético y requiriendo soluciones de rehabilitación efectivas. Los enfoques tradicionales de rehabilitación a menudo carecen de accesibilidad y personalización, lo que motiva el desarrollo de dispositivos innovadores que se alineen con las necesidades específicas de los atletas.
Método: se utilizó un enfoque de métodos mixtos, integrando análisis cualitativos y cuantitativos. La recolección de datos incluyó entrevistas con fisioterapeutas y atletas, complementadas con observaciones en

campo en academias de fútbol. El proceso de diseño combinó metodologías de Diseño Centrado en el Usuario (UCD) y TRIZ para identificar y resolver contradicciones, llevando a una solución óptima. Herramientas como software CAD y técnicas de prototipado rápido facilitaron el desarrollo del dispositivo.
Resultados: el dispositivo resultante demostró ser eficaz en la recuperación de esguinces agudos de rodilla. Los atletas reportaron reducción del dolor, mejor movilidad y tiempos de recuperación más cortos. Las métricas cuantitativas, como la fuerza muscular y la estabilidad articular, mostraron mejoras significativas, mientras que los comentarios cualitativos destacaron la comodidad y facilidad de uso del dispositivo.
Conclusiones: el dispositivo de rehabilitación representa una contribución novedosa a la medicina deportiva, particularmente para academias de fútbol. Su diseño innovador aborda los requisitos específicos de los atletas, mejorando su proceso de recuperación y rendimiento. A pesar de su potencial, se requieren estudios adicionales para validar su eficacia en poblaciones más amplias y disciplinas deportivas diversas. Esta investigación resalta la importancia de integrar diseño, tecnología y experiencia médica para desarrollar soluciones de rehabilitación impactantes.

Palabras clave: Diseño Industrial; Diseño; Materiales; Dispositivos de Rehabilitación.

INTRODUCTION

The industry has grown considerably by improving the quality of products sold in this field, implementing new technology and experimenting with new materials.[1] This great step towards a better experience presents a great disadvantage for Ecuador, since the prices to import these products demand a large investment, consequently producing a high cost of use.[2] For this reason, this project shows the panorama of rehabilitation devices in a sports context for one of the most important joints of the human body, the knee, which highlights its importance in the mobility and stability of the human body.[3]

Injuries in soccer require specialized medical treatment, since this target group not only needs to recover from the injury but also strengthen their joint to continue their sports activity.[4] The objective of this research is to design and develop a rehabilitation device tailored to the needs of soccer athletes, focusing on enhancing recovery from injuries and improving joint stability through innovative methodologies and materials.[5] For this reason, the professionals from the Rehabilitation Center were considered for their expertise in treatments for athletes.[6] The team of professionals who support this project contribute significantly with their knowledge and direction on the subject, for which interviews and field visits have been developed to understand the importance and use of rehabilitation devices.[7] Being an industrial design project, product design professionals have been selected to learn about the scope of the project, rapid prototyping techniques, and materials present in the national market. For the methodological development, the TRIZ and DCU methods have been considered, strategically selecting stages of each of these methodologies and combining them for the benefit of the project, as well as bibliographic documentary research due to the complexity of the subject.[8]

METHOD

The research method that will be used in the project is the inductive method, due to its ability to provide a deeper and more detailed understanding of the subject of study. This methodology emphasizes flexibility and adaptation according to the progress of the research.

The project is based on the combination of aspects related to User-Centered Design (UCD) and the TRIZ method as shown in figure 1. Tools such as interviews will be used to obtain information to determine the users' needs. Likewise, the physiotherapist, who is part of the academy's technical team, will be interviewed to obtain guidance on health and well-being aspects for the correct development of the project. Finally, through (CAD) and (PR) tools, articulated physical parts will be generated.[9]

For the development of the methodology that will be applied in the project, the following steps have been considered because of the combination of the methodologies mentioned above:

1. Research and analysis.
2. Data collection.
3. Problem.
4. Problem formulation.
5. Contradictions.
6. Solution of contradictions.
7. Design.
8. Prototyping.
9. Assessment.

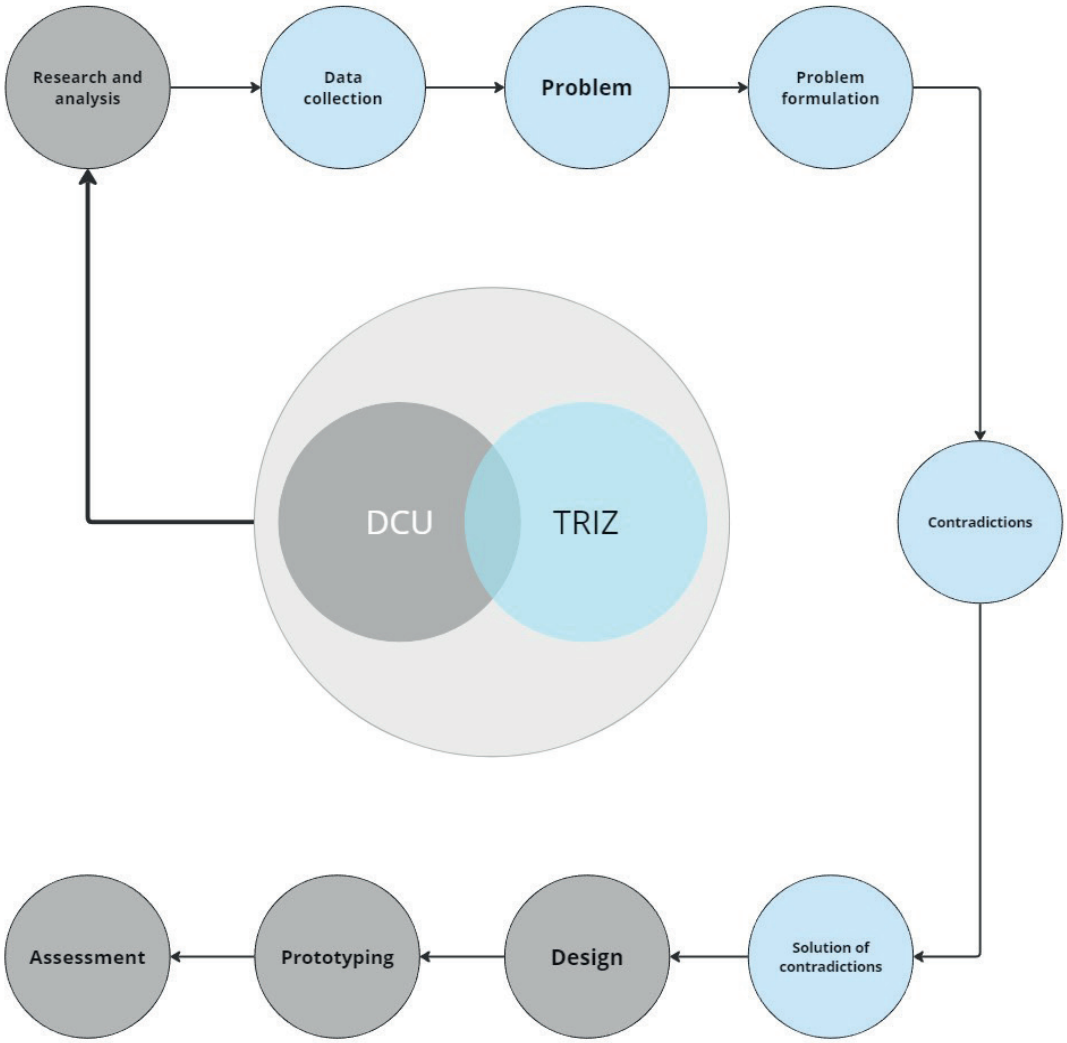

Figure 1. Combined methodology
Note: essential aspects of DCU and TRIZ have been linked for the development of the methodology implemented in this project

Population and sample

Table 1 presents the characteristics of the target population, which will be composed of young adults aged 20 to 24 years who have suffered from knee injuries in the sports context. Non-probabilistic snowball sampling will be used to consider the study's participants. The target population is expected to allow the determination of the relevant characteristics of the demographic group to obtain considerable results for the project.

Table 1. Relevant characteristics of the target group

Feature	Description
Age	20 to 24 years
Sex	Men
Activities	Active participants in sports, preferably soccer.
Acute knee sprain	Recent knee injuries due to twisting, falls or impacts during sports.
Physical activity level	High-performance or amateur athletes.
Risk factors	Previous history of injuries, lack of adequate training, inappropriate sports equipment, playing conditions, among others.
Access to health care	Availability and access to health services.
Treatment strategies	Physiotherapy and rehabilitation.

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RESULTS

The approach of this project is mixed, that is, qualitative and quantitative. The quantitative data allow obtaining information that highlights the incidence and impact of injuries in sport, complemented by the qualitative data that highlights the experiences or perceptions in relation to the rehabilitation process and the devices used. This allows enhancing the process of rehabilitation of injuries in the athletes of the soccer academy, as well as their physical development. The study's findings highlight the effectiveness of the designed rehabilitation device in aiding athletes with acute knee sprains. Participants reported reduced pain, increased mobility, and improved recovery times. Furthermore, subjective feedback indicated high levels of satisfaction and acceptance of the device, suggesting its potential as a valuable tool in sports injury rehabilitation.

Table 2. Fisher test developed by the physiotherapist for athletes

Degrees of flexion		101,60°	10,288
Degrees of extension		0°	0
Muscle Strength	Scarce (0-3)	1	3,30 %
	Good (4)	3	10 %
	Normal (5)	26	86,70 %
Coronal Stab.	Yeah	7	23,30 %
	No	23	76,70 %
Estab. Sagittal	Yeah	28	93,30 %
	No	2	6,70 %
Pain	Mild (0-3)	22	73,30 %
	Moderate (4-6)	5	16,70 %
	Severe (7-10)	3	10 %
alpha angle (femoral)		95,95°	2,383
beta angle (tibial)		87,97°	1,294
femorotibial angle		4,05°	2,421
femoral sagittal angle		2,31°	4,343
tibial sagittal angle		91,99°	1,571

The treatment progress was evaluated weekly, with a weighting scale from 1 to 5 based on the frequency and effectiveness of rehabilitation sessions. During week 1, two sessions were conducted, and the progress was rated as 1. In week 2, another two sessions resulted in an improved rating of 2. By week 3, the frequency increased to three sessions, leading to a progress rating of 2-3. In week 4, three sessions maintained steady progress, with a rating of 3. Finally, in week 5, two sessions showed significant improvement, achieving a progress rating of 4-5.

Table 3. Results of the satisfaction survey conducted with injured athletes

		Yes	No
Sex	Male	8 (88,9 %)	1 (11,1 %)
Age	< or = 70a	8 (80 %)	2 (20 %)
Degrees of flexion	Flexion > or = Me	18 (94,7 %)	1 (5,3 %)
Degrees of extension	Extension > 0 = Me	23 (85,2 %)	4 (14,8 %)
Muscle Strength	4-5 MRC Scale	26 (89,7 %)	3 (10,3 %)
Coronal Stab.	Yeah	6 (85,7 %)	1 (14,3 %)
Estab . Sagittal	Yeah	24 (85,7 %)	4 (14,3 %)
Pain	0-5 EVA Scale	23 (85,2 %)	4 (14,8 %)

Research limitations/implications

While the developed rehabilitation device showed promising results, the study had some limitations. The sample size was relatively small, limiting the generalization of the findings. Additionally, the study focused exclusively on athletes from soccer academies, potentially limiting its applicability to other sports. Future research could address these limitations by conducting larger-scale studies involving athletes from diverse sports

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backgrounds to further validate the device's efficacy and applicability across different athletic populations.

The table represents essential aspects for defining the target group, such as age, gender, injury and the form of treatment used to combat the ailments. Table 4 divides the potential market considering the characteristics and needs of the target group to which it is directed.

Table 4. User segmentation

Geographic variable	Continent	South America
	Country	Ecuador
	Province	Tungurahua
	City	Ambato
Demographic variable	Age	20 to 24 years
	Gender	Male
	Target group	People who have suffered knee injuries
	Marital status	Singles
Socioeconomic variable	Education level	Primary Secondary Higher education
	Professional partner category	Average Medium High
	Occupation	Students Professionals Workers
Psychographic variable	Personality	Determined, team player, disciplined, competitive, resilient, passionate, skilled at making decisions and shows leadership.
	Lifestyle	Training routine, a balanced diet, adequate rest, avoiding harmful habits, smart and focusing on personal development.
	Interests	They include family, charity, education, music and other sports.
	Preferences	Certain types of soccer cleats and specific equipment.
Behavioral variable	Priorities	Performance on the field, health and fitness, professional development and representation of their country.
	Benefits	Health Comfort Welfare
	Customer situation	Athletes from the soccer academy in the city of Ambato
	Frequency	Daily sports activities except for weekends.

The table shows variables that allow the user to be identified and stratified to learn more about aspects that may be relevant in the design process, such as age, preferences and the sports context.

Practical implications

The findings of this study have practical implications for athletic trainers, sports physicians, and rehabilitation specialists. The developed rehabilitation device offers a novel approach to managing acute knee sprain injuries in athletes from soccer academies. Implementing this device in rehabilitation programs could potentially accelerate the recovery process, improve treatment outcomes, and enhance athletes' overall performance and well-being. Additionally, the device's portability and ease of use make it a feasible option for use in both clinical settings and training facilities, providing a valuable tool for injury prevention and management in the field of sports medicine.

Effective recovery from knee injuries includes medical diagnosis, treatment and gradual return everyday activities. This process must be continuously supervised by a specialist who certifies the recovery, since if the patient does not achieve the necessary strengthening in this joint, he will not be able to maintain the necessary performance that the sports activity demands. For this reason, this project will not only contribute to the

rehabilitation of injuries by supporting medical development but also aims to contribute to the academy in the training and performance process of athletes. This knee rehabilitation device has operational relevance, since in the city there are health professionals who can contribute with their expertise in medical aspects, in addition, soccer is considered one of the largest sources of income and expenses, as well as the interest reflected in the commercial market. Finally, this product is important because it improves the patient's experience during the rehabilitation process, enhances the use of their own strength as a motor system to generate resistance and result in a stronger knee. In summary, the aim is to improve the therapeutic experience in the recovery process of acute sprain injuries, promote the recovery of athletes and contribute to the academy in its training process, balancing socioeconomic development in the medical area in addition to reaffirming the citizen's right to develop in an environment that guarantees their health, integrity, safety and well-being.[10]

Rehabilitation is one of the most important points within the injury recovery process. Over the years, knowledge about basic science has improved and criteria such as anatomy, biochemistry and technology have been incorporated, which have managed to improve the protocols implemented within rehabilitation.[11]

The treatment program gives its greatest importance to joint mobility (flexion and extension) by means of the different techniques or devices that the rehabilitation center has as detailed in Table 5, which allow to optimize the movement and elasticity necessary in this joint. Therefore, it is necessary to perform movements with opposition or resistance that will allow to strengthen all the muscles, ligaments and tendons that will result in greater strength, resistance and stability.[4]

Table 5. Sports physiotherapy treatment

Process	Detail	Images
Assessment	Evaluate the injury and general condition of the knee to determine the best course of action.	
Pain reduction	Combination of manual therapy, massage, and heat and cold therapy to help reduce knee pain.	
Muscle strengthening	Specific sports physiotherapy exercises such as strengthening the muscles surrounding the knee, reducing pressure on it, and preventing future injuries.	
Improved mobility	Stretching and mobility exercises.	
Preventing future injuries	Through muscle strengthening and improved mobility.	

The sports physiotherapy program allows for effective recovery from specific injuries in the shortest possible time. The process detailed in the table that begins with the evaluation and ends with prevention planning is the most frequent sequence used by physiotherapists. The evaluation of a knee injury detailed in table 6 is a process developed by the medical specialist, which allows the treatment to be assigned according to the severity of the injury.

Table 6. Knee Injury Assessment

Process	Detail
Medical history	Gather information about the patient's medical history and current injury, including when it occurred, how it happened, and what symptoms the patient is experiencing.
Physical examination	The patient's knee is examined to assess range of motion, muscle strength, stability, and sensation.
Diagnostic tests	Perform diagnostic tests to determine the severity and cause of the injury.
Functional assessment	Perform functional assessment tests to determine how the injury is affecting the patient's ability to perform daily activities, such as walking or climbing stairs.
Goal setting	Develop a treatment plan.

When a patient presents a knee injury, he or she is exposed to the following comprehensive evaluation program that allows the identification of determining factors to understand the history of the injury and establish an effective and safe treatment.

Social implications: Soccer is one of the most popular sports worldwide, where it not only categorizes age or gender, but can reach different levels, contexts, cultures, and countries. Taking this into account, it is estimated that there is a total of 270 million people, or an equivalent of 4 % of the world's population, actively participating in this sport.[12] In Ecuador, the sport of soccer has progressively developed across different regions. According to Villacís et al. (2009), 31,6 % of the population practices sports, with the highest participation observed in the Amazon region (40 %), followed by the Andean region (36,4 %), and lastly, the Coast region (26,5 %). These statistics highlight the growing importance of soccer in the national context and its impact on health and physical activity.

The originality of this research lies in the development of a specialized rehabilitation device tailored specifically for acute knee sprain injuries in athletes from soccer academies. By addressing a specific need within the sporting community, this study adds value by offering a novel solution that contributes to injury prevention and management in the field of sports medicine. Furthermore, the device's innovative design and functionality distinguish it from existing rehabilitation equipment, providing athletes with a unique tool to aid in their recovery process and ultimately enhancing their performance and overall well-being.

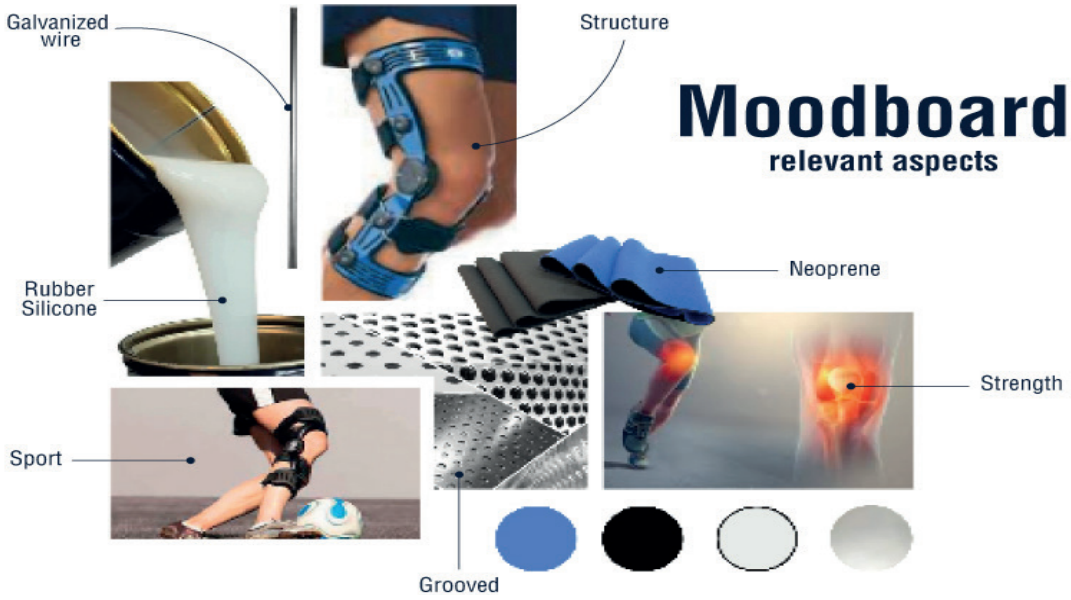

Figure 2. Moodboard

CONCLUSIONS

The development of a rehabilitation device for athletes with acute knee sprains represents a significant innovation in the field of sports medicine, particularly within soccer academies. This study demonstrated that integrating methodologies such as User-Centered Design (UCD) and TRIZ, alongside advanced tools like CAD software and rapid prototyping, provides tailored solutions that address the specific needs of athletes. Improvements were observed in mobility, muscle strength, and recovery times, with a high level of user acceptance in terms of comfort and ease of use.

However, further research is required to validate the device's effectiveness across larger populations and diverse sports contexts. Additionally, exploring more sustainable materials and reducing production costs are critical areas to ensure its scalability and accessibility. These findings align with the objective of designing a specialized device for sports rehabilitation, contributing to technological innovation in sports medicine and emphasizing the value of interdisciplinary collaboration between industrial design, technology, and medicine.

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The authors declare that there is no conflict of interest.

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