Report 2: Assisted Respiratory Therapy with Percussive Vest and Digital Monitoring

Pulmo-Vest

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Abstract- This document presents the development of a project focused on the design of biomedical systems. It analyses and discusses real needs that could be addressed, identifies related technologies, and compares them with the proposed solution. The study details the technical specifications of the percussive vest, its intended functions, and expected performance. Specifically, this project aims to support respiratory therapy through the design of a percussive vest that generates controlled mechanical oscillations to aid in pulmonary clearance. Additionally, a spirometer is integrated to record pulmonary data and monitor patient progress. A LabVIEW-based interactive interface is developed to guide patients through therapy sessions and ensure proper execution. This report provides a comprehensive overview of the design, technical considerations, and development plan for the proposed system, ensuring its feasibility and effectiveness in respiratory therapy applications.

INTRODUCTION

Problem statement

In recent years, international organizations such as the World Health Organization have overseen monitoring and looking for factors of change in the face of global problems in the health sector. To date, it is reported that every two seconds people between the ages of 30 and 70 die prematurely due to non-communicable diseases, such as cardiovascular diseases, diabetes, cancer, and chronic respiratory diseases. The World Health Organization seeks to reduce this premature mortality rate by a third by 2030 through prevention and treatment protocols, in turn promoting mental health and general well-being related to these diseases. To address these problems, good health is essential for sustainable development. With this, the UN 2030 agenda relate these two concepts considering economic and social inequalities, as well as environmental factors and emerging challenges with non-communicable diseases.

Different problems in the health sector have been pointed out, where the field of engineering seeks to contribute in different ways to mitigate these and move towards sustainable development for global health. With new advances in science and technology, there is great potential to be able to develop new protocols to address global health issues.

Among the problems pointed out in "Emerging trends and technologies: a horizon scan for global public health" of the UN, we find 2, which could be related to chronic respiratory diseases as mentioned above, although they do not speak directly of respiratory diseases, they are problems that can encompass the need that we seek to satisfy with the use of engineering technologies.

1. **Pandemic preparedness and prevention:** This point establishes that there is an area of significant improvement in pandemic preparedness and response through trials of therapeutic interventions and preparation of post-pandemic protocols. From this last point the following

analysis is derived. After having lived through the COVID 19 pandemic, many patients who were infected by this virus were able to recover, however, many came to present considerable sequelae to recover their original lifestyle. The main sequelae that have been recorded can be shown on Table 1:

Afectación clínica secular y consecuencias del coronavirus más frecuentes.

Tejido o sistema	Síntomas seculares asociados a la COVID-19
Vía aerea respiratoria superior	Grado residual de anosmia y/o ageusia Tos
Vía aerea respiratoria inferior	Disnea de esfuerzo Tos Secreción mucosa Dificultad para inspiración profunda Dolor torácico
Muscular	Debilidad generalizada Dolores erráticos
Neurocognitivo	Falta de atención Pérdida de memoria Mala calidad del sueño Insomnio
Psicológico	Ansiedad Depresión
Digestivo	Atragantamiento Cambio en el ritmo deposicional Sensación de plenitud
Otros	Pérdida de peso

Table 1. Clinical affectation, sequelae and stronger consequences of the coronavirus (Molina-Molina, 2020).

2. **Digital diagnosis and surveillance:** On this point, it establishes itself as "Digital Health", which encompasses the use of information, electronics, and telecommunications for medicine. There is talk of portable devices, databases, and information technologies for medicine. Mainly the devices that we have for this point are monitoring devices.

Then again, as biomedical engineers, it is essential to provide a therapy that helps the patient recover their respiratory capacity through high-frequency vibrations and the recording of respiratory volumes, which are stored and opens the possibility that the therapy can be performed remotely, without the need for the patient to go to a health center while the therapy is being performed.
This point is complemented by the provisions of the Global Health Strategy 2025-2028, in the section "Health information systems strengthened, and digital transformation implemented".

Justification

Our project seeks to create a system aimed at respiratory problems, specifically in the upper and lower respiratory tract. The main objective is to develop a therapeutic system that helps patients to recover their respiratory capacity by means of high frequency vibrations. In addition, the system will record and store respiratory volumes, which will allow therapy to be carried out remotely, without the need for patients to visit healthcare centres. In addition to addressing health problems, our project will promote the integration of digital tools, medical records and information systems. With the development of this therapy device, we seek to specifically address issues arising from diseases such as asthma, chronic obstructive pulmonary disease (COPD) and the increasingly prevalent post-COVID-19 complications. (Molina-Molina, 2020). Our project targets a wide range of patients, including elderly people with respiratory impairment. The design of our device, unlike others that work with percussions, allows elderly people to be candidates for this type of therapy, as it does not generate shocks to the rib cage. It can also be directed to patients recovering from respiratory infections, procedures that required intubation, and as mentioned before, patients with chronic respiratory diseases such as asthma, COPD or some form of pulmonary fibrosis. In addition to addressing health problems, our project will promote the integration of digital tools, medical records, and information systems. These systems will help to eliminate inequalities and structural barriers, such as gender differences, market segmentation, economic inequalities, etc. In terms of gender and market segmentation, we are looking for a design that can be adapted to the user's body depending on their physical characteristics. Likewise, this device could even be used by athletes or professionals who are exposed to continuous respiratory stress. People with limited access to healthcare, such as those in rural areas, who need remote treatment solutions. By providing an accessible, non-invasive, technology-driven solution, we aim to improve the quality of life of these people while reducing hospitalization rates.

By ensuring a people-cantered approach, we aim to improve the effectiveness of health programs, enhance real-time monitoring, and improve the management of healthcare resources. This digital transformation will modernize data systems, improving healthcare access and performance.

The economic impact of respiratory diseases is significant, as hospitalizations, medications and long-term therapies increase healthcare costs for both patients and governments. Our solution seeks to reduce hospital visits through home therapies, generating savings for healthcare institutions and reducing costs for patients by making treatment more accessible. In terms of social impact, the project promotes equity and inclusion in healthcare by addressing structural barriers such as gender disparities, ensuring equal access to respiratory therapies, considering the needs of people with motor disabilities, and overcoming geographic limitations through remote healthcare solutions for underserved populations. (“DOF - Diario Oficial de La Federación,” 2020).

In terms of environmental impact, considering that traditional respiratory treatments often require disposable medical devices, face-to-face clinic visits and energy-intensive hospital equipment, our project contributes to environmental sustainability by reducing the need for transportation to health centers, decreasing carbon emissions, minimizing medical waste through a reusable therapy system and promoting digital health solutions that reduce paper-based medical records and administrative processes. By integrating technology with healthcare, we seek to improve both human and environmental well-being.

State of art

Respiratory diseases, including chronic obstructive pulmonary disease (COPD), asthma, and post-COVID-19 complications, significantly impact global health. The development of biomedical systems for respiratory therapy has gained prominence in recent years, leading to advances in digital health, high-frequency chest wall oscillation (HFCWO), and spirometry-based monitoring systems. This section provides an overview of the latest developments in these technologies, highlighting their contributions to respiratory therapy and patient care.

- High-Frequency Chest Wall Oscillation (HFCWO)

This is a non-invasive therapy used to aid mucus clearance in patients with pulmonary conditions. Devices such as the inCourage system (RespirTech, n.d.) and the AffloVest (AffloVest, 2025) employ oscillatory forces to mobilize secretions and enhance pulmonary function. These vests are particularly beneficial for patients with cystic fibroids, bronchiectasis, and neuromuscular diseases (Hill-Rom, 2019). Studies have shown that HFCWO therapy improves airway clearance, reduces pulmonary infections, and enhances patients´ quality of life (Graham et al., 2019).

- Digital Spirometry and Remote Monitoring

Digital spirometers have revolutionized respiratory care by enabling continuous monitoring of lung function. Devices like the Vernier Spirometer (Vernier Science Education, 2023) and Medical Technologies´ spirometry solutions provide real-time data on lung volumes and flow rates. These systems integrate with digital health platforms, allowing healthcare providers to track patient progress remotely (LabView, 2022). The integration of remote monitoring reduces hospital visits, promotes early detection of pulmonary decline, and facilitates personalized treatment plans (Graham et al., 2019).

- Integration of IoMT in Respiratory Therapy

The Internet of Medical Things (IoMT) has significantly enhanced patient-centered care by enabling data-driven decision making. IoMT based respiratory therapy systems incorporate cloud-based platforms, mobile applications, and wearable sensors to provide real-time feedback and analytics (Global Health Strategy, 2025). Research indicates that IoMT driven solutions improve patient adherence to therapy and optimize treatment outcomes (Molina-Molina, 2020).

Advancements in artificial intelligence (AI) and machine learning have further improved respiratory diagnostics and therapy personalization. AI-driven spirometry interpretation, automated anomaly detection, and predictive modeling of disease progression are actively being researched (Ogrodnik, 2013), Additionally, the integration of telemedicine into respiratory therapy has expanded access to healthcare, particularly for patients in remote areas (WHO, 2022).

The development of innovative biomedical systems for respiratory therapy has significantly improved patient outcomes. HFCWO vests, digital spirometry, IoMT based monitoring, and AI driven diagnostics are revolutionizing respiratory care. Future research should focus on enhancing device affordability, increasing accessibility, and optimizing user-friendly interfaces to further improve patient adherence to treatment and health outcomes.

General description of the idea

This project involves developing a wearable respiratory therapy vest designed to help patients improve lung function through controlled vibratory therapy. The vest is intended to be adjustable so that it can comfortably fit a range of body sizes while providing a stable platform for the integration of the necessary components.

At the core of the design are DC motors that create oscillations across the front and back of the thoracic region. These motors, which operate between 2 and 25 Hz, will be managed through Arduino UNO, allowing for the desired control over the therapy sessions. Another important aspect of the project is the measurement of lung capacity before and after the therapy. This involves capturing respiratory data, which will provide valuable feedback on the effectiveness of the treatment. Although we are not planning to directly analyze the lung capacity data as part of this project, the design will facilitate the monitoring and visualization of the latter by using an interface on LabVIEW, a platform that facilitates real time data acquisition and processing. Our university provides access to LabVIEW and various electrical components, including an external power source, which allows us to focus on integrating and testing the vest without needing to purchase these items.

In general, our idea is to create a versatile, wearable device that not only delivers therapeutic vibrations to enhance respiratory function but also facilitates the monitoring and visualization of lung capacity data. This approach could serve as an important step towards more effective at-home respiratory therapy solutions, even though the direct analysis of the data is not within the scope of this initial project phase.

HYPOTHESIS

The development of this device will enable the integration of the rehabilitation phase and the measurement of lung capacities, facilitating the monitoring of respiratory therapies.

OBJECTIVES

Main objective

The main objective of our project is to develop a therapy system that combines the rehabilitation phase with lung capacity measurement to enhance the monitoring of respiratory therapies. This system includes a vest designed to deliver high-frequency vibrations and an interface that allows patients to perform therapy remotely while tracking their lung capacity measurements.

Specific objectives:

- Record lung capacity measurements using LabView.
- Design an adjustable vest that incorporates DC motors to provide high-frequency vibrations for respiratory therapy.
- Improve patient follow-up by integrating rehabilitation and lung capacities measurement in a single system.
- Develop a user-friendly interface that enables patients to conveniently perform therapy at home.
- Validate the functionality of the prototype and the accuracy of lung capacity measurements.

TECHNICAL SPECIFICATIONS

Technical specifications		
Number	Comment	Source
1	Adjustable vest. • Designed to accommodate various body sizes while maintaining secure and comfortable positioning.	[3]
2	Oscillation Mechanism: • Capable of producing oscillations within the range of 2 to 25 Hz. • Compatible with control interfaces such as Arduino UNO.	[4]
3	Lung capacities measurement: • Flow rate measurement: ±10 L/s • Internal volume allowance (dead space): 93 mL.	[34]
4	PC Software: • Compatible with LabVIEW for data acquisition and analysis.	[15]
5	Environmental conditions • Designed to work in relative humidity levels ranging from 15% to 93%, without condensation.	[14]
6	Working Temperature • Recommended to operate within an ambient temperature range of 18 to 28°C	[25]

7	Electrical requirements for the entire system: • Requires an external 12 V DC power source.	[4]
9	Cleaning requirements: • Hands must be washed before and after the start of the therapy. • The vest and spirometer must be disinfected with a sanitizer after each therapy session. • The spirometer tube must be disposable.	[12]
10	Calibration requirements: • No calibration is required, as the therapy parameters are pre-established.	[24]

Table 2. Technical Specifications.

Performance		
Number	Comment	Source
1	The vest will generate vibrations in the anterior and posterior thoracic cage from 2 to 25 Hz with motors. There will be 4 stimulation points, meaning 4 motors in total; 2 motors placed on the anterior thoracic cage and 2 on the posterior thoracic cage.	[7]
2	Lung capacity measurement will be conducted using a spirometer and an NI USB-6009 acquisition card with the following characteristics: • Flow rate: ±10 L/s • Dead Space: 93 mL • Nominal Output: 128 mV/[L/s] • Detachable Flow Head	[8,34]
3	The system will store therapy data on the PC daily and weekly, with a maximum of two recordings per day	[20]
4	The therapy will last 30 minutes, divided into 12 steps of 2.5 minutes. • Each therapy session will last 30 minutes, divided into 12 steps of 2.5 minutes each. The vibration frequency will follow a pre-set pattern: It will increase from 6 Hz to 15 Hz over 2.5 minutes, then decrease from 15 Hz to 6 Hz over the next 2.5 minutes. This cycle will repeat continuously for the full 30-minute session. • User configurable parameters: • Start button. • Emergency stop button (pause).	[20]
5	User-Configurable Parameters: • Start button • Emergency stop button (pause)	[20]
6	The vest will be adjustable to fit different patients	[20]
7	The interface will guide patients on when and how to breathe to start measurements, following a predefined reference and will indicates the start of therapy.	[16]

Table 3. Performance.

FLOWCHART TO SHOW METHODOLOGY

Figure 1 illustrates the methodology we will follow throughout the semester for the development of our project. It is divided into four stages, each representing a key phase of the process. Additionally, the timeline for each stage is provided, along with the assigned team members responsible for each task.

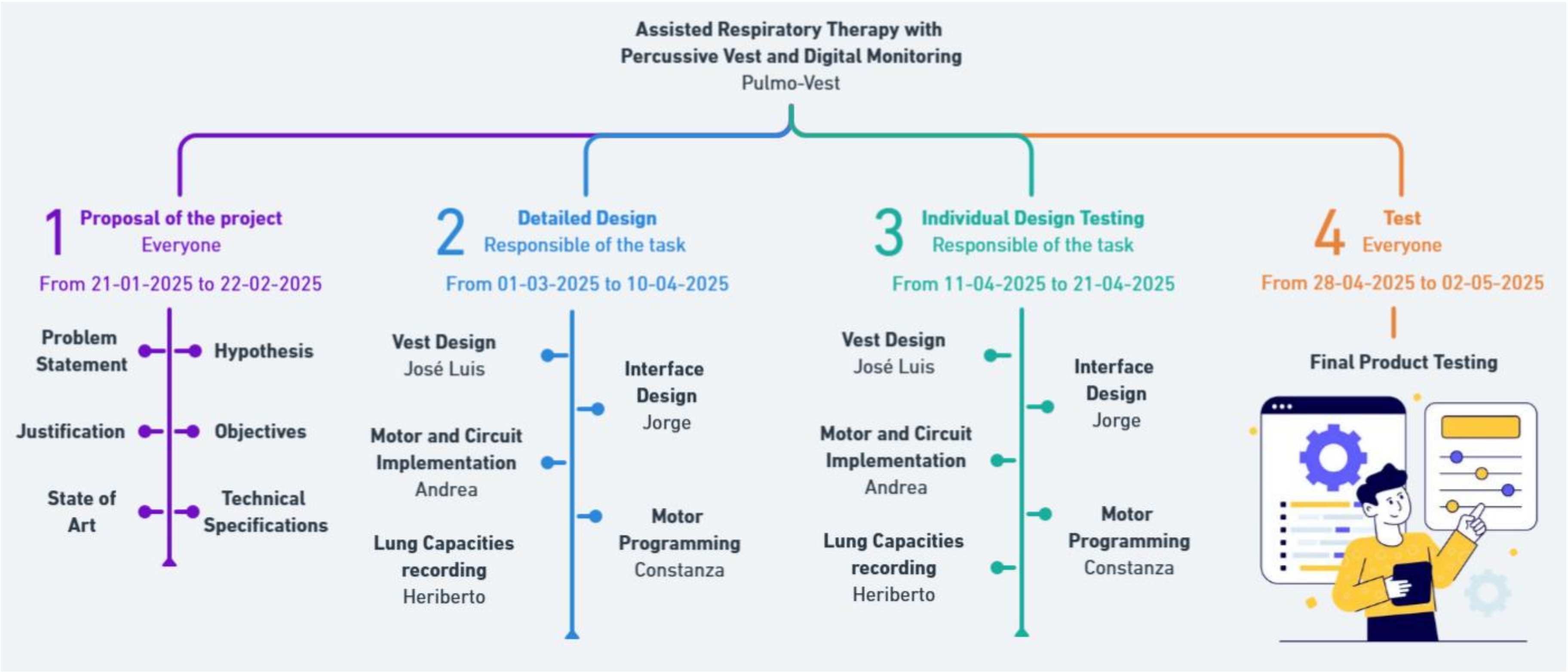

Figure1. Flowchart to show methodology.

WORK PLAN INDICATING ALL THE TASKS AND THE RESPONSIBLE OF EACH ONE

Once we were sure about our project plan, we created a Gantt Diagram to organize the tasks, set deadlines, and assign responsibilities. Following this schedule is important to achieve the expected results and meet our goals. Figure 2 shows the Gantt Chart with all the key details.

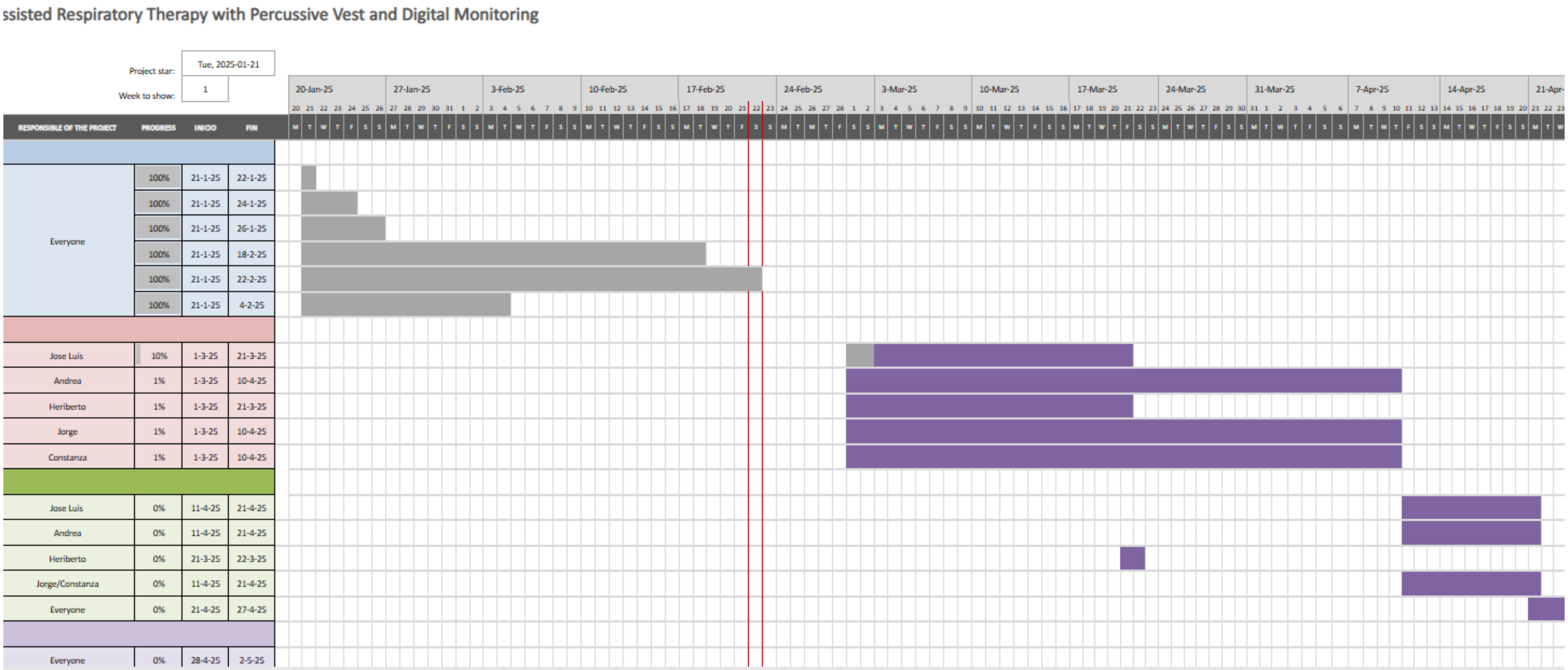

Figure 2. Gantt Diagram.

Additionally, we have provided the link to the online Excel file, where it is possible to view the real-time updates and track the progress of the project tasks: [Diagrama de Gantt simple.xlsx]

PRELIMINARY BUDGET

The following list provides an initial overview of the items that would need to be purchased for the project. The materials include the adjustable vest components, the vibratory system parts (DC motors and their encasings, motor drivers, and the vibration distribution board), as well as the items needed for assembling and modifying the vest (Velcro, adjustable strips, sewing kit, and fabric). Meanwhile, other resources such as LabVIEW software and certain electrical components are available through our university's electronics laboratory.

- **RS-550 Micro Motor DC**
  - Quantity: 4
  - Unit Price: $214 MXN each
  - Total Price: $856 MXN
  - Source: [31]
- **Small Motor Encasing**
  - Quantity: 4
  - Unit Price: $50 MXN each (estimated)
  - Total Price: $200 MXN
- **L293D Motor Driver**
  - Quantity: 2
  - Unit Price: $89 MXN each
  - Total Price: $178 MXN
  - Source: [30]
- **Surtek Vest**
  - Quantity: 2
  - Unit Price: $224 MXN each (estimated)
  - Total Price: $456 MXN
  - Source: [29]
- **Velcro (8 m x 20 mm)**
  - Quantity: 1 unit
  - Total Price: $178 MXN
  - Source: [31]
- **Beyourd 1 Inch Buckle and Strap Set**
  - Quantity: 1
  - Total Price: $201 MXN
  - Source: [6]
- **Vida4u Sewing Kit**
  - Quantity: 1
  - Total Price: $199 MXN
  - Source: [35]
- **Fabric**
  - Quantity: 2 meters
  - Total Price: $200 MXN
  - Source: [19]
- **Acrylic plate (40 x 60cm x 3mm)**
  - Quantity: 1
  - Total Price: $390 MXN
  - Source: [1]

Total preliminary budget: $2,858 MXN

ANNEXES

Regulatory and statutory		
Number	Comment	Source
1	NOM-241-SSA1-2021 Good manufacturing practices for medical devices.	[25]
2	NOM-036-1-STP-2018 Ergonomic risk factors in the workplace - Identification, analysis, prevention, and control.	[26]
3	NOM-240-SSA1-2012 Installation and the operation of techno vigilance.	[27]

Table 4. Regulatory and statutory.

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