PORTABLE PHOTOTHERAPY LIGHT FOR NEONATAL CARE

Portable phototherapy light for neonatal care/01/SSUET (2020s)/2023:

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Certification

This is to certify that **Kinza Imran**, **2020-BM-026** and **Alveena, 2020-BM-007** have successfully completed the final project **Portable Phototherapy Device For Neonatal care,** at the **Sir Syed University Of Engineering & Technology**, to fulfill the partial requirement of the degree **Biomedical Engineering.**

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Portable Phototherapy Device For Neonatal Care

Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9 ✓	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3 ✓	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8 ✓	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	
4	Familiarity of issues	Involve infrequently encountered issues	
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	Consequences	Have significant consequences in a range of contexts.	
8	Interdependence	Are high level problems including many component parts or sub-problems	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

Our final year project is a Phototherapy light designed basically to cure and provide light therapy for new born babies who are have weak immunity and are prime targets for Jaundice (increased levels of Bilirubin). Moreover, this device is not only for hospital use but for homes and family usage.

Our device contains Penta light (meaning light of 5 levels). This light is the main source for therapy, the blue light (UV light). We are also using variable power supply, battery back-ups, and PVC material for outer shape of the device.

This guideline applies to neonates within the first two weeks of life. Artificial lighting (usually fluorescent) has been used for the past 30 years in the treatment of neonatal jaundice. Widely differing light outputs and spectra are used, making comparison and evaluation difficult for clinicians. Phototherapy for jaundice is a common treatment in neonatal medicine and is used to prevent the neurotoxic effects of bilirubin. Studies have assessed the optimal wavelength of phototherapy light, the importance of irradiance and spectral power, and the types of light source, including the use of single versus multiple light sources. Neonatal hyperbilirubinemia is caused by an increase in blood bilirubin levels above the normal range. An increase in the levels of unconjugated bilirubin is the most common manifestation of neonatal jaundice.

Keywords: jaundice, bilirubin, phototherapy

Undertaking

I certify that the project **Phototherapy light for neonatal care** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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2020-BM-007

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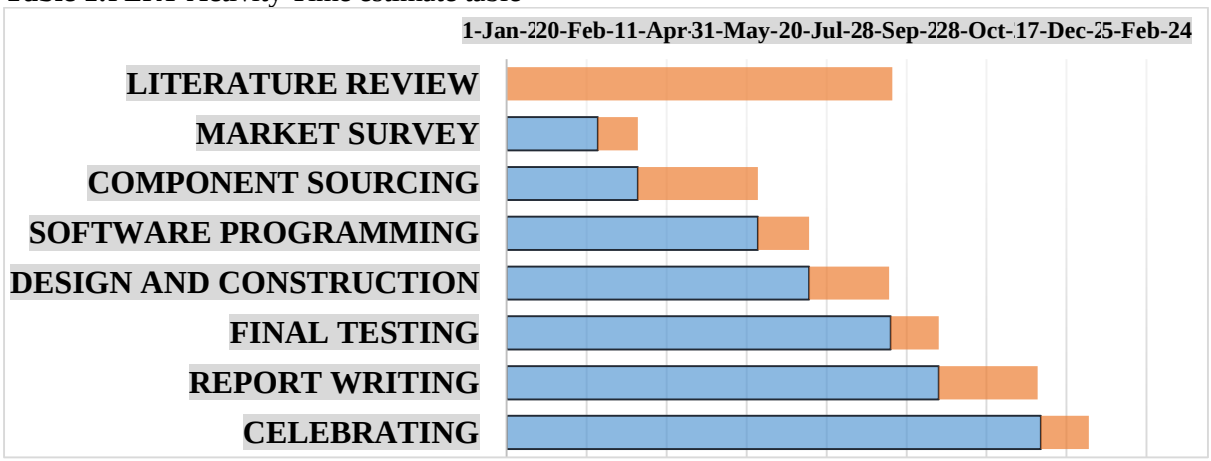
We truly acknowledge the cooperation and help make by **Engr. Dr. Sidra Abid Syed. Designation** of **Sir Syed University Of Engineering & Technology.** She has been a constant source of guidance throughout the course of this project. We would also like to thank **Engr. Dr. Sidra Abid Syed** from **Chairperson Of Biomedical Engineering Department**, **Sir Syed University Of Engineering & Technology** for his help and guidance throughout this project. We are also thankful to our friends and families whose silent support led us to complete our project.

Table of Contents

List of Tables

Table 1:PERT Activity Time estimate table



This approximately depicts the Gantt chart of our project, initiated in 2022. Notably, the project has now been successfully completed and is ready for commercialization.

List of Figures

List of Equations

Equation 1:

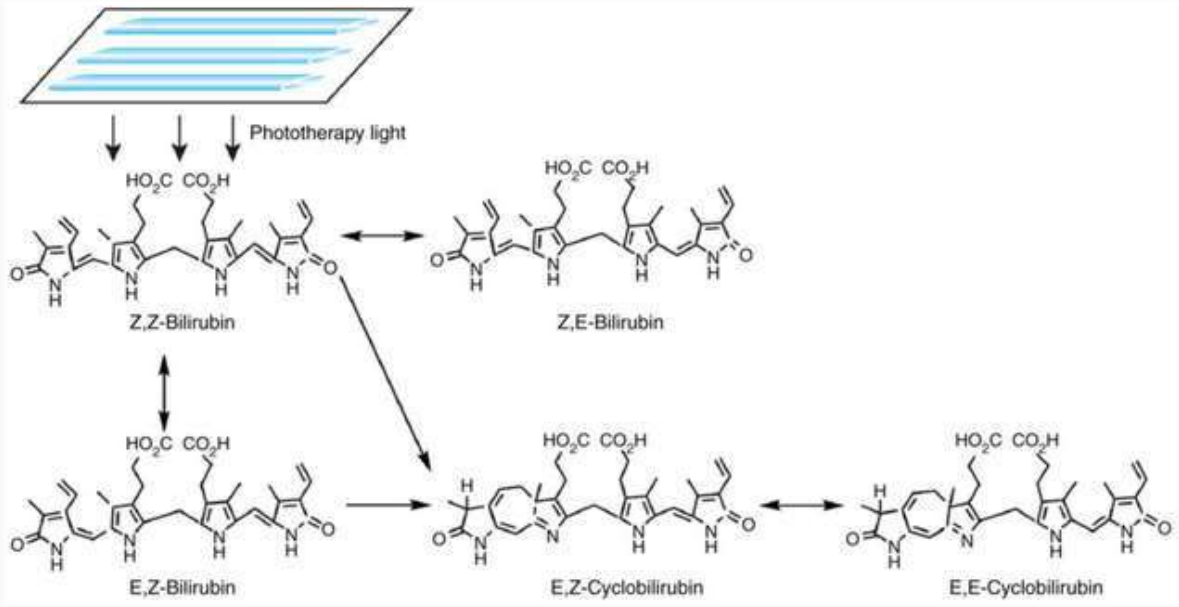


Figure 2 - Mechanism of action of phototherapy for neonatal hyperbilirubinemia. Upon exposure to light, non-polar unconjugated bilirubin (Z,Z-bilirubin) in the skin is converted into water-soluble bilirubin isomers, including Z,E-bilirubin, E,Z-bilirubin, E,E-bilirubin, E,Z-cyclobilirubin and E,E-cyclobilirubin.

Chapter 1

1.1 Introduction

The title of our project is **"PHOTOTHERAPY DEVICE FOR NEONATAL CARE**". The aim of this study is to cure and provide light therapy for new born babies who are have weak immunity and are prime targets for Jaundice (increased levels of Bilirubin). Moreover, this device is not only for hospital use but for homes and family usage.

Proposed solution contains Penta light (meaning light of 5 levels). This light is the main source for therapy, the blue light (UV light). We are also using variable power supply, battery back-ups, PVC material for outer shape of the device, GSM module and we are incorporating a touch screen panel.

This guideline applies to neonates within the first two weeks of life. Artificial lighting (usually fluorescent) has been used for the past 30 years in the treatment of neonatal jaundice. Widely differing light outputs and spectra are used, making comparison and evaluation difficult for clinicians[1]. Phototherapy for jaundice is a common treatment in neonatal medicine and is used to prevent the neurotoxic effects of bilirubin. Studies have assessed the optimal wavelength of phototherapy light, the importance of irradiance and spectral power, and the types of light source, including the use of single versus multiple light sources [2]. Neonatal hyperbilirubinemia is caused by an increase in blood bilirubin levels above the normal range. An increase in the levels of unconjugated bilirubin is the most common manifestation of neonatal jaundice [3].

1.2 Statement of the problem

The phototherapy unit we are designing is different in because we want to alter the conventional parameters to obtain the most optimal results, for example, placement, distance, added layers etc. We also want to include a battery back-ups, and control panel and make it portable.

1.3 Goals/Aims & Objectives

Aim of this project is to design an efficient phototherapy light and are objective is clear, we want to design a cost effective unit which we can market later to all the local hospitals in the city. Our aim is to make this device common in all neonatal departments in all hospitals in the city, to ultimately reduce the rate of new born deaths due to jaundice (which is a leading cause).

The difference in our unit will be, that it will be designed to be portable, have a GSM unit, have a touch screen panel control, have a more variety of settings (options) and alongside, will be cost effective. Also, we will use rechargeable battery back-ups because currently available phototherapy devices don't really have that facility

1.4 Motivation

This project is not just an FYP for us but we're intimately connected with executing it because we've realized the cause it is for and the effect it will have on the quality of life for neonatal babies.

1.5 Assumption and Dependencies

The need for a portable phototherapy device in neonatal care is significant, particularly in resource-limited settings. Technological advancements make this feasible, as the necessary components, like LED light sources and battery power, are easily integrated into a compact and portable device. Additionally, the device will be designed to be affordable and cost-effective compared to existing solutions, while maintaining safety through the inclusion of features that minimize the risk of harm to infants.

Bringing this portable phototherapy device from concept to reality necessitates addressing several key dependencies. Financial resources are crucial to support development and commercialization, requiring access to adequate funding. Additionally, collaboration with experts in engineering, design, and medical device development is vital to ensure the device's technical feasibility and safety. Regulatory support from relevant bodies will guide the design and ensure compliance with all necessary standards. Furthermore, successful completion of clinical trials is essential to demonstrate the safety and efficacy of the device for its intended use. Establishing partnerships with reliable manufacturers and distributors will facilitate production and ensure efficient distribution to target markets. Finally, implementing a well-designed marketing and sales strategy will be crucial to reach target audiences and drive adoption of the device. Addressing these dependencies is critical to ensuring the success of this project and its potential impact on neonatal healthcare.

1.6 Methods

First we will start by designing our circuit on proteus and run it there to avoid any errors and complications. After thorough analysis on the software, we will move on to Hardware design.

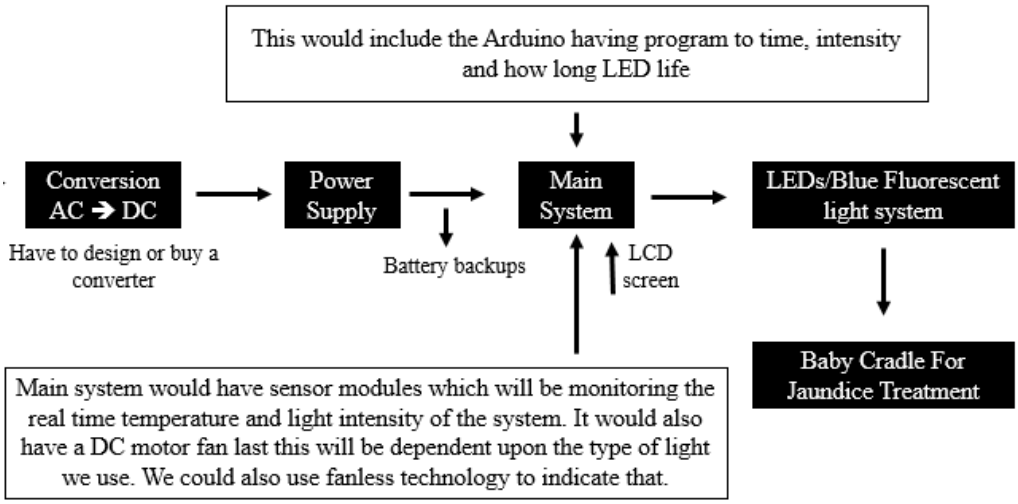


Figure 1.1: Block Diagram of the system

1.7 Report Overview

This report outlines the development of a novel portable phototherapy device designed to address the needs of both hospital and home environments. It aims to improve the accessibility and effectiveness of phototherapy treatment for neonatal jaundice, particularly in resource-limited settings.

The report details the problem statement, highlighting the limitations of existing phototherapy units. It then presents the proposed solution, featuring a penta light source, variable power supply, battery backup, durable casing, GSM module for remote monitoring, and a user-friendly touchscreen interface.

The significance and motivation of the project are emphasized, highlighting the potential impact on reducing newborn mortality rates associated with jaundice. The report further outlines the key assumptions and dependencies for project success, including market need, technological feasibility, cost-effectiveness, safety, and access to funding and expertise.

The proposed methods encompass design and simulation, hardware development, testing and evaluation, refinement, clinical trials, and commercialization.

This project presents a promising solution for improving neonatal care by providing a portable, cost-effective, and user-friendly phototherapy device. By addressing critical assumptions and

dependencies and successfully implementing the outlined methods, this project has the potential to make a significant contribution to improving the health outcomes of newborns worldwide.

Chapter 2

2.1 LITERATION REVIEW

2.1.1 Creation

In the 1950s, Dr. Richard Cremer developed the first phototherapy machine to treat jaundice in newborns. This replaced blood transfusion as the standard treatment due to its simplicity and effectiveness. Phototherapy uses visible light to lower bilirubin levels, and is the most common treatment for jaundice today.

2.1.2 Jaundice

While common, especially in premature and breast-fed babies, infant jaundice arises from an immature liver's inability to remove bilirubin effectively. Yellowing skin and eyes signal the condition, diagnosed through visual exams or blood tests. Further investigation might be needed for prolonged cases, with severity dependent on various factors like birth weight and gestational age.

2.1.3 Bilirubin and Its Impact In Jaundice

Bilirubin, which is responsible for the yellow color of jaundice, is a normal part of the pigment released from the breakdown of "used" red blood cells. Newborns produce more bilirubin than adults do because of greater production and faster breakdown of red blood cells in the first few days of life. It is toxic and it must be transformed by the liver so it can be removed from the body. As red blood cells are breakdown, they release hemoglobin. Heme molecules (from hemoglobin) are converted to bilirubin.

Conjugated or indirect Bilirubin is bound to serum albumin and transferred to the liver where it is conjugated to glucuronate by glucuronyl transferase to be removed by the body. Normally, the liver filters bilirubin from the bloodstream and releases it into the intestinal tract. A newborn's immature liver often can't remove bilirubin quickly enough, causing an excess of bilirubin. Jaundice due to these normal newborn conditions is called physiologic jaundice.

2.1.4 Modern Device

Now a days, phototherapy machine uses halogen bulbs, light emitting diodes (LED) and Fluorescent lights. Combinations of light are also effective, while the use of LED lights out down the generation of excessive heat. Fluorescent tubes or halogen lamps have been used as light sources for phototherapy for many years. But they have drawbacks like producing heat, high energy consumption and it also requires frequent changes of their short life span which make it costly. LEDs are supposed to be more efficient than other light sources in phototherapy. Light-emitting diodes (LEDs) have recently been investigated as possible alternatives in phototherapy units. LEDs produce low heat so that they can be placed very close to the infant. The life span of LEDs is longer and their energy consumption is lower than that of the conventional light sources, which make them more cost-effective. It also results in greater decrease of total serum bilirubin (TSB) level and short duration of phototherapy. And there is no such major side effect associated with the use of led as a treatment source.

Figure 2.1: portable phototherapy device for neonatal care

2.1.5 Advancement

In a comparison, between fluorescent and led based phototherapy device used for the treatment of preterm infants with neonatal jaundice, it has been found that the result were almost the same expect the led based phototherapy results in less frequent hyperthermia. The results were similar with most of the previous reports indicating that LEDs units are as effective as conventional phototherapy units. [6,7] The previous studies has shown the comparable side effect of led and non-led based phototherapy, it has found that severe cases of hyperthermia results in patients are associated with fluorescent tube used for phototherapy and also conventional phototherapy units have halogen or fluorescent light source result in a significant increase of trans epidermal water loss in preterm infants, and these side effect was not observed with LED units. [8] This study considers led based phototherapy with regard of safety and efficacy to be a better option than the conventional phototherapy with halogen or fluorescent light sources in preterm infants because the leds based phototherapy has less frequent side effects, less energy consumption, longer life span, and lower costs.

Chapter 3

3.1 Materials And Methods

1. 3.1.1 Basic Idea Of the Project

Basic idea of the project is to design a device that efficiently reduce increased level of bilirubin in new born babies as initial health facility for the prevention of jaundice. Phototherapy changes unconjugated bilirubin into oxidized bilirubin and its structural isomers that can be easily excreted.

To proceed this device some parameters and configurations is in consideration. Those parameters include light intensity, distance of the infant from the light source, and how much body area is exposed during treatment. The greater the light intensity, the faster the bilirubin levels decline in the blood stream.[9] To increase the light intensity, the distance between the infant and apparatus must be decrease. And the greater the surface area of the body exposed during treatment, the more efficient phototherapy will breakdown bilirubin in blood.

2. 3.1.2 Model Design

- Microcontroller
- Blue LEDs
- Resistors
- Potentiometer
- LCD screens
- Buttons
- Acrylic Sheets
- Temperature sensors
- DC power supply
- Steel pipes
- Breadboard
- Vero-board

3. 3.1.3 Commercialization of the Phototherapy Device

Through its innovative technology and demonstrably superior efficacy, this phototherapy device stands poised to revolutionize the field of neonatal jaundice treatment, offering a demonstrably safer and more effective alternative to conventional methodologies. We are excited to announce its commercial availability, marking a significant advancement in the care of newborns affected by this prevalent condition.

Figure 3.1 : Prototype Of Project

4. 3.1.4 Quantitative Approach

Distance of LEDs from baby will be approximately **40-45cm**. Wavelength of Blue LEDs is **450-490nm** and irradiance is calculated as **30-40 µW/cm²/nm**. Device is operated on approximately **12 volts** DC power supply having current of **1 Ampere.**

5. 3.1.5 Quantitative Approach

The proposed device is designed to offer five intensity levels using a potentiometer controlled by an Arduino. This feature allows for precise and adaptable treatment based on the individual needs of each infant.

The device will also be equipped with a battery backup option, ensuring uninterrupted treatment even in the absence of a power source. Additionally, a display will be incorporated to indicate the remaining battery life, providing valuable information for treatment planning and avoiding unexpected interruptions.

Finally, the device will be attached to a cot for optimal comfort and convenience during treatment. This configuration allows for easy positioning of the light source and ensures the infant's safety and stability.

Overall, the proposed device represents a significant advancement in phototherapy technology, offering enhanced efficacy, flexibility, and ease of use for both healthcare professionals and families

Chapter 4

2. 4.1 Proposed Solution/Results & Discussion

The device utilizes a potentiometer to control and adjust the intensity of the phototherapy light. By varying the resistance of the potentiometer, the voltage applied to the LEDs is altered, resulting in changes in light intensity. This allows for precise and adaptable treatment, catering to the specific needs of each infant.

Five distinct intensity levels are available: very high, high, medium, low, and very low. This range provides healthcare professionals with the flexibility to administer the appropriate dose of phototherapy based on the individual's condition.

Greater light exposure is generally associated with better treatment outcomes. Therefore, maximizing the surface area of the infant's body exposed to the light is crucial. The device's design and positioning facilitate this, ensuring optimal treatment efficacy.

In essence, the potentiometer acts as a control knob, allowing for precise adjustment of the phototherapy light's intensity, ultimately tailoring the treatment to each individual's needs.

Figure 4.1: Showing the temperature and humidity and Also the battery life.

Chapter 5

3. 6.1 Summary and Future work

Neonatal jaundice, a common newborn condition marked by skin and eye yellowing, arises from insufficient bilirubin processing by the liver. While often harmless and self-resolving, severe cases require treatment. This thesis presents a novel, portable phototherapy device specifically designed for resource-limited settings like rural hospitals, addressing the unequal access to effective jaundice treatment.

Motivated by the limitations of existing devices (expensive, bulky, AC-powered), this thesis proposes a cost-effective, portable solution with key features:

- **Accessibility**: Affordable due to readily available materials and minimal complex components.
- **Mobility:** Compact and lightweight for easy transport and deployment in diverse settings.
- **Comfort**: Integrated cot ensures patient comfort and stability during treatment.
- **Versatility**: Five adjustable intensity levels cater to individual infant needs.
- **Reliability**: Uninterrupted treatment guaranteed by battery backup even without AC power.
- **Safety**: DC power supply eliminates electrical risks, enhancing safety in diverse environments.

Extensive research informed the device's design and development. Testing and evaluation confirmed its effectiveness:

- Adjustable intensity provides optimal treatment for varying bilirubin levels.
- Battery backup ensures continuous care even in power outages.
- DC power minimizes electrical hazards, promoting safe use in various environments.

To optimize treatment outcomes, recommendations include:

- Parental use of eye pads to protect infants from potential light exposure.
- Regular bilirubin monitoring to adjust treatment intensity as needed.

- Adherence to healthcare professional guidance and recommendations.

This portable phototherapy device represents a significant advancement in neonatal care, offering an accessible, affordable, and effective solution for improved treatment in resource-limited settings. This contributes to a future with equitable access to quality healthcare for all.

Future work could include integrating bilirubin monitoring and AI for personalized treatment, exploring low-cost manufacturing and alternative energy sources, conducting long-term clinical trials and investigating applications beyond jaundice, all aimed at making this device even more accessible and effective for improving neonatal care worldwide.

Chapter 6

7.1 Conclusion & Recommendation

This thesis has presented the design, development, and testing of a novel portable phototherapy device for treating neonatal jaundice in resource-limited settings. The device addresses the unmet needs of newborns and families in these areas by offering a safe, effective, and cost-effective solution.

7.1.1 Key findings and achievements:

- The device is significantly more affordable than conventional phototherapy units, making it accessible to a wider population.
- Its compact and lightweight design allows for easy transport and deployment in diverse settings, including rural hospitals and clinics.
- The integrated cot provides comfort and stability for infants during treatment.
- The adjustable intensity levels cater to individual infant needs and ensure optimal treatment efficacy.
- The battery backup option ensures uninterrupted treatment.
- The device operates solely on DC power, minimizing electrical hazards and enhancing safety for both infants and healthcare professionals.

7.1.2 Recommendations:

- **Dress your baby appropriately**: Remove any unnecessary clothing and accessories that may obstruct the light. A diaper is sufficient during treatment.
- **Protect your baby's eyes**: Use soft eye patches or shields provided by your doctor. This will protect their eyes from the bright light.
- **Monitor your baby closely**: Watch for any signs of discomfort, such as fussiness or skin irritation. Report any concerns to your doctor immediately.
- **Maintain hygiene**: Wash your hands thoroughly before and after handling your baby. Keep the treatment area clean and sanitized.
- **Follow feeding schedules**: Continue breastfeeding or bottle-feeding your baby as usual. Phototherapy does not interfere with feeding.

- **Stay informed**: Ask questions and discuss any concerns with the healthcare professionals caring for your baby.
- **Be patient**: Phototherapy treatment may take several days depending on your baby's bilirubin levels. By implementing these recommendations, this portable phototherapy device has the potential to significantly improve the quality of care for newborns with jaundice in resource-limited settings. It offers a promising solution to address the existing healthcare disparities and ensure that all infants have access to the treatment they need.

Overall, this project demonstrates the feasibility and potential impact of innovative technologies in addressing healthcare challenges in underserved communities. It paves the way for further research and development of accessible and affordable solutions to improve the health and well-being of newborns worldwide.

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