

Portable phototherapy hut, a multi- disciplinary approach to neonatal jaundice. An analytical study.

Marvin Mayambala*, Jonathan Ocen, Emmanuel Ogwang, Alice Martha Namilo, Emmanuel Omongo
Department of Biomedical Engineering, Kampala School of Health Sciences.

Page | 1

Abstract

Background:

Neonatal jaundice is one of the most common illnesses in newborn infants all over the world. Phototherapy is an effective and widespread treatment for this condition. This project aimed at designing a cost-effective, portable device to treat jaundice in both home and hospital settings.

Methodology:

This was an analytical study aimed at testing the working prototype after the design process, which is economically and technologically viable in order to develop a portable phototherapy machine.

Results:

The existing components of phototherapy equipment, conventional phototherapy equipment, LED phototherapy equipment, and fiber-optic phototherapy equipment were reviewed to come up with a cost-effective, portable phototherapy hut. The project used a multi-disciplinary idea model to design a cost-effective and portable device to treat jaundice from both home and hospital. A double-sided illuminating phototherapy device, with a weighted assessment, 18.38(33), was considered.

Conclusion:

When designing a phototherapy hut, various comparisons were made to choose a solution without any bias, in the weighted criteria assessment, which ranked the best.

Recommendation:

The use of phototherapy machines should not be limited only to health facilities, but can also be extended for home use.

Keywords: Phototherapy hut, Neonatal jaundice, Light Emitting Diode, Prototype.

Submitted: March 04, 2024 **Accepted:** February 17, 2026 **Published:** April 06, 2026

Corresponding author: Marvin Mayambala

Department of Biomedical Engineering, Kampala School of Health Sciences

Background

Neonatal jaundice is one of the most common illnesses in newborn infants all over the world. It affects about 50% of term and 80% of preterm babies, which usually appears 2 to 4 days after birth and usually resolves spontaneously after 2 weeks (Paul Woodgate, Luke Anthony Jardine, 2010). Phototherapy is an effective and widespread treatment for this condition. In phototherapy treatment, narrow-spectrum blue light of wavelength 460- 490 nm is projected onto the infant's skin.

The blue light converts bilirubin into isomers, structural isomers, and photo-oxidation products that are water-soluble and can easily be excreted by the kidneys. Phototherapy devices or units are machines that are used to deliver phototherapy treatment to infants with jaundice. Jaundice occurs when bilirubin is formed faster than it can be cleared from the body by the liver (Richard Idro, 2004).

In the market, based on the type of equipment, the phototherapy equipment is divided into conventional phototherapy equipment, LED phototherapy equipment, and fiber-optic phototherapy equipment. They are further categorized as per the type of lamp installed in conventional phototherapy equipment; they include the equipment with fluorescent lamps and the equipment with compact fluorescent lamps. The fluorescent lamp devices come in two different sizes, namely, full body phototherapy equipment and partial body phototherapy equipment.

According to the International Electro-technical Commission (IEC), specifications call for measurements in terms of light energy per surface area over a narrow frequency band (Gehealthcare, n.d). And lux meters are rated specifically for LEDs and used to rate the Firefly phototherapy light in terms of irradiance. The IEC specifications define phototherapy intensities as follows: "effective" phototherapy: at

least 10 $\mu\text{W}/\text{cm}^2/\text{nm}$, and "Intensive" phototherapy: greater than 30 $\mu\text{W}/\text{cm}^2/\text{nm}$.

The Phototherapy device manufacturing industry has a broad range of participants who include, but are not limited to: GE Healthcare, Koninklijke Philips N.V, Natus Medical Incorporated, Beurer, Herbert Waldmann GmbH & Co. KG, PhotoMedex, Inc, MTTs ASIA, VIA Global Health, and others, and Design that Matters. All the above companies capitalize on the needs of the biotechnology companies, hospitals, diagnostic centers, clinics, academic research institutes, and government institutions.

Phototherapy can help increase the rate of bilirubin clearance. This is because the light causes the bilirubin to undergo photochemical reactions that allow it to be excreted in the bile or urine (Oh W, 2003). When treated with therapies such as phototherapy, jaundice is very curable. However, when unmonitored or untreated, jaundice can lead to death. Unfortunately, phototherapy devices are not prevalent in all parts of the developing world. As a result, there is a great need for an affordable, locally manufactured photo-therapy device that can be used in hospitals and clinics, most especially Kayunga regional referral hospital. This project aimed at designing a cost-effective, portable device to treat jaundice in both home and hospital settings.

Methodology

Study design

An analytical design was adopted for this project, where available technologies were analyzed and compared to the

proposed photo-therapy blanket to assess how much better the latter is, and where it needs improvement.

Study area

The study was carried out at Kampala School of Health Sciences, with reference to Kayunga regional referral hospital.

Firefly phototherapy device

This device provides a 41 microwatt per centimeter-squared per nanometer ($\mu\text{W}/\text{cm}^2/\text{nm}$) irradiance to the baby during treatment with the 6 high-power LEDs from the canopy and 18 high-power LEDs in the bottom base, which cover 95% of the surface area of the neonate. These high-power LEDs are easily focused to the center, where the area of focus is by the lenses that are put at the top of each LED. It was designed by Design that Matter in 2012. Design that Matters is a nonprofit design company that partners with others to design products that address basic needs in developing countries (Jonathan, 2012). This design lacks a battery, which could facilitate the product's usage in remote areas and in areas where there is frequent load shedding. It has a high-power consumption because of the very many high-power LEDs in use at the same time. It is slightly inflexible, and the baby may find slight discomfort during treatment due to the 22cm width of the bowl where they are placed. This bowl is small in width, and therefore, the baby cannot move freely during treatment. This product is also relatively expensive compared to the phototherapy blanket, whose cost is less than \$350. It is slightly rigid to carry, given its size, which is slightly larger than the phototherapy blanket.



Figure 1: Shows the firefly device, indicating the canopy and the base on which the bowl, in which the neonate rests during treatment.

Product design specifications.

Parameter	Specifications
Power	(110 - 230)AC, 50/60 Hz, 100VA
Dimensions	Base: (70,000 x 40,000 x 35,000)mm, (L X W X H) Minus the mobile stand.
Light output	Wave length: (450-479)nm
Illuminated area	(50,000x40,000)mm, (LXW)
LED life	>60,000 Hours
Mobile stand	Height: 10,000mm
Mattress	Neonatal mat, covered with a sterilized linen
Power unit and circuit system	Separate from the frame, Dimensions: (14X10X4) inches, (LXWXH)

Table 1: Showing the product design specifications.

Targeted customers

The major targeted customer was Kayunga regional referral hospital. However, this device must reach the levels of serving each kind of customer to work in the NICU and pediatrics departments of a health facility. On top of that, this device would also reach safety precautions for home use.

Storage/ transport.

The device would be portable with a stand connected to the wheels, hence making it easy to transport from one place to another.

Production materials

The baby was to be laid on the neonatal mat covered with a sterilized linen. The device has no latex at any point, hence reducing the effects of the anaphylaxis to the neonate.

The tent would be made up of an opaque, sterilized linen that covers the phototherapy light, while at the fore end, near the head of the baby, would be a mosquito net. Since this device is designed for home use too, factors may arise with keeping the baby from the mosquitoes, and this will be catered to in our design.

Material	Specification
Power supply	Linear regulated power supply.
Transformer	toroidal transformer
Rectifier	Full bridge rectifier
Regulators	LM7812 LM 337T
Phototherapy LEDs	High power (100W 440-465)nm LED
Frames	Light metallic iron bar frames

Table 2: Shows the production materials and some of their specification.

Overhead phototherapy devices

Most overhead devices have adjustable height settings, with LED technology or the use of fluorescent tubes to produce the blue light. They are usually placed on the head post of the bed, and the light shines from the upper surface of the baby, which gives them one-sided light. These devices need to be positioned correctly with their overhead lamps; otherwise, they do not provide the right treatment (Oksaku, 2006). Despite the fact that overhead

phototherapy devices are intended to treat one infant at a time, clinicians in overcrowded, under-resourced hospitals attempt to treat many infants in the same device at once. This results in ineffective doses of phototherapy for all infants treated, and a higher risk of cross-infection (CDC, 2013). By integrating the infant bed into the overall design and placing the lights at a non-adjustable, fixed distance.

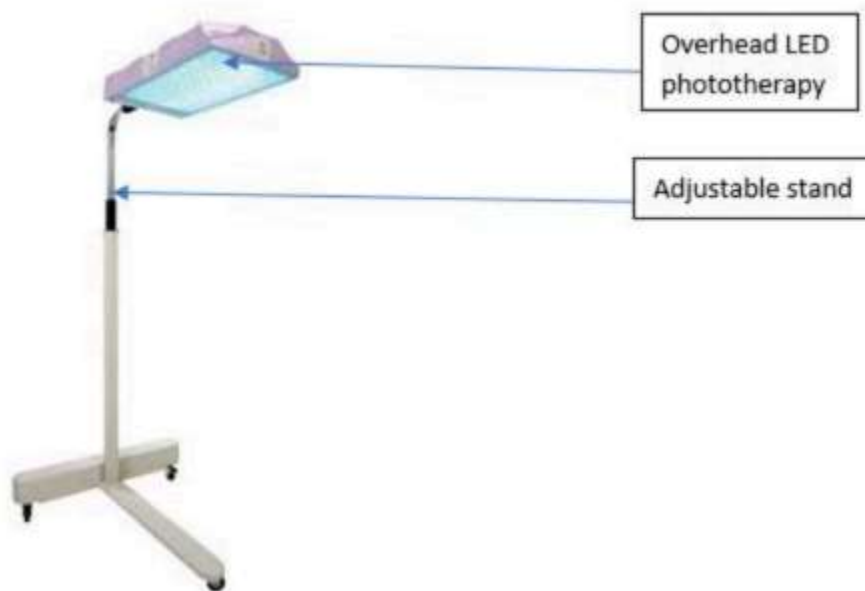


Figure 2: Shows an overhead LED phototherapy device with an adjustable stand. Photo adapted from the internet

Bili Blanket Phototherapy System

This system uses fiber optics and represents advanced technology in phototherapy treatment given in the hospital or at home. The Bili blanket provides the highest level of therapeutic light available to treat one's baby. The strength of light from the Bili blanket is about the same as one would get in the shade on a sunny day, and this is actually safer because the Bili blanket filters out potentially harmful ultraviolet and infrared energy.

A pad of woven fibers is used to transport light from a light source to the baby. This covered fiber optic pad is

placed directly against the baby to bathe the skin in light. Absorption of this light leads to the elimination of bilirubin. With the convenience of this design, a child can be diapered, clothed, held, and nursed during treatment. Its increased surface area, high spectral in-radiance, and long-lasting blue, narrow-band LED light are just the beginning (Al, 2013).

The figure below shows the Bili blanket phototherapy device with the generator connected to the fiber-optic pad on which the neonate rests when receiving treatment. This device is a product of General Electronics (GE).



Figure 3: Shows the Bili blanket phototherapy device that is manufactured by GE. Photo adapted from the GE website.

Bili blankets offer the possibility of treating some degrees of jaundice at home as long as the baby is otherwise healthy. This makes them quite popular with parents, doctors, and insurance companies, who would otherwise have to pay for more expensive inpatient treatment. Some also consider it a better option because the newborn does not have to be separated from the parents and does not need to lie alone in a box with his or her eyes covered. The baby is tied to the machine, unless they can wheel it around, and there is a stiff pad between the mother and baby.

The whole setup consists of the light generator, termed the light box, the fiber-optic cable through which the light is carried, and the light pad, which is a 25 cm x 3 cm pad that is attached to the baby.

Home treatment with such a Bili blanket is risky since the baby's skin is in contact with the light fiber, which can burn them. The bili blanket also covers a small surface area of the baby during treatment, which increases the treatment time compared to the proposed blanket, which has a higher surface area of treatment (Walker et al, 2012).

It is a heavy device with a relatively big generator, which makes it inconvenient to carry around compared to a one-piece phototherapy blanket.

Results

Project idea selection.

Enough research work was made upon the ideas, and finally three solutions were screened out: designing a phototherapy machine, designing a phototherapy blanket, and designing a phototherapy hat.

An expanded illumination overhead phototherapy machine.

An overhead device that has adjustable height settings, with LED technology or the use of fluorescent tubes to produce the blue light. It can be placed on the head post of the bed, and the light shines from the upper surface of the bed, which can be used to work on two babies.

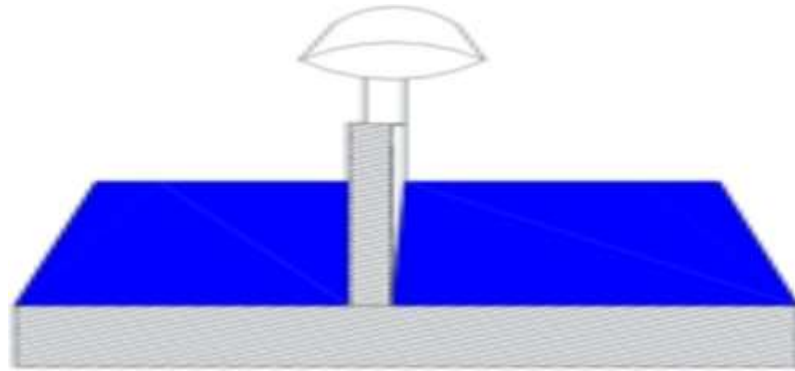


Figure 4: Shows the design of an overhead phototherapy machine.

Canopy tent

This tent uses canopies to filter/ remove harmful rays from sunlight. This is a low-cost and effective way to give phototherapy to quite a large number of neonates.

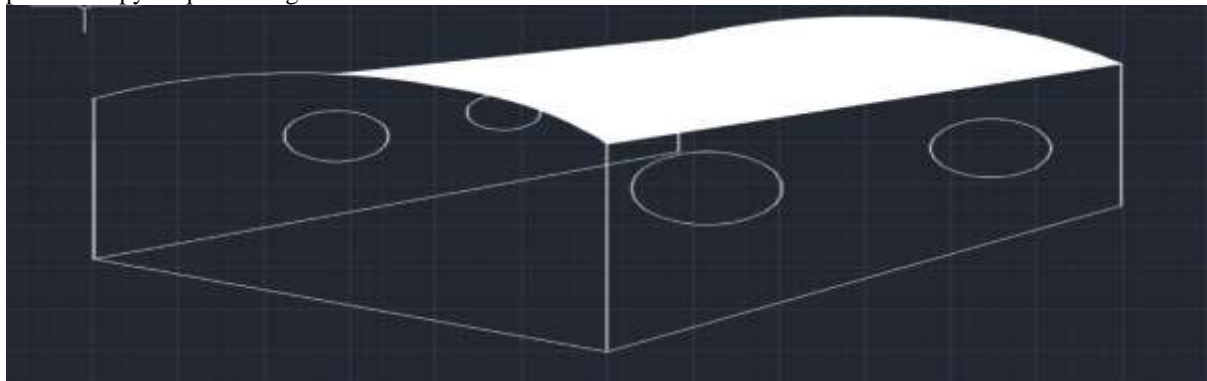


Figure 5: Shows a phototherapy canopy tent.

Double-sided illuminating phototherapy device

The phototherapy hut can be designed when a baby is lying on the mat, and light is shone from both the hut and the mat. This means that light can be provided from all sides of the baby, not as an overhead photo therapy machine.

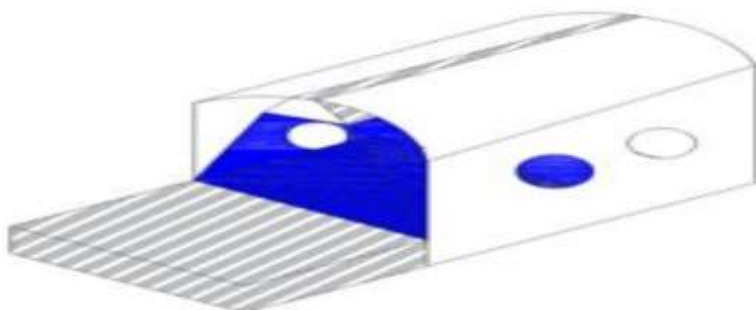


Figure 6: Shows the design of a phototherapy hut.

Weighted criteria assessment.

After selecting the three major ideas from the twelve solutions, specifications that helped to weigh the three solutions were weighed in order to select the most suitable based on the client's likes and dislikes.



Figure 7: Shows the team members during the weighted criteria assessment session.

During this procedure, the specifications were ranked from 1 to 6. These ranks were used to calculate the weights of these specifications with the formula below;

$$W = (1 - ((i - 0.5) / 6)) \times 100;$$

Where, i = rank.

Specifications	Rank (i)	W
Portability	2.5	67
Illuminated area	4	42
Low power consumption	6	8
Low purchase cost	5	25
Comfort ability	2.5	67
Number of babies to accommodate	1	92

Table 3: Showing the weighted assessment criteria.

0 – poor, 2 - fair, 4 – fair good, 6 – good, 8 – very good, 10 – excellent.

The grading is indicated in the brackets () as shown in the table

specification	w	An expanded illumination overhead phototherapy machine.	Canopy tent	double side illuminating phototherapy device
Portability	67	5.36(8)	0(0)	6.03(9)
Illuminated area	42	1.68(4)	1.68(4)	3.78(9)
Low power consumption	8	0.32(4)	0.8(10)	0.4(5)
Low purchase cost	25	1(4)	1(4)	1(4)
Comfort ability	67	4.02(6)	0(0)	5.35(4)
Number of babies to accommodate	92	1.82(2)	9.2(10)	1.82(2)
total		14.2(28)	12.68(24)	18.38(33)

Table 4: Showing the weighted assessment criteria.

Conclusion

As a design matters group, designing a photo therapy hut solution was chosen without any bias because it was compared with other solutions in the weighted criteria assessment and ranked the best.

Acknowledgement

It is always a pleasure to remind the fine people at Kampala School of Health Sciences of the sincere guidance we received to uphold my practical skills in this profession.

First of all, thanks to the Almighty God for the gift of life and our families for giving encouragement and invaluable assistance to us. Without all this, we might not have been able to complete this project properly. Secondly, we would like to thank the administration of Kampala School of Health Sciences for giving us the opportunity to

practice the multi-disciplinary design 1 within the institution.

We would like to express our special thanks to our project supervisor and trainer, Eng. Namilo Alice Martha, the tutor of Biochemistry and Instrumental Analysis at KSHS, as well as the Multi-disciplinary Design Project I tutor, Eng. Omongo Emmanuel for the guidance he has given us in this project.

We sincerely express our gratitude to Mr. Ogwang Emmanuel and his special staff for all their dedication, energy, guidance, and knowledge.

We are extremely grateful to our department staff members and friends, mainly course mates, who helped us in the successful completion of this project. A paper is not enough for me to express the support and guidance we received from them for almost all the work we did there.

Finally, we apologize to all other unnamed who helped us in various ways to have a good training.

List of abbreviations

NICU	Neonatal Intensive Care Unit
BP	Blood Pressure
NIBP	Non-Invasive Blood Pressure
LED	Light Emitting Diode
CPAP	Continuous Positive Airway Pressure
ECG	Electro Cardiogram
SpO2	Spatial Oxygen
Bpm	Beats per minute.
ICU	Intensive Care Unit.
HR	Heart Rate.
MOTH	Main Operating Theatre
ME	Medical Equipment
Mr.	Mister
Dr.	Doctor
PIG	Project idea generation
PIS	Project idea selection

Source of funding

The study was not funded.

Conflict of interest

The author declares that there was no conflict of interest.

Author contributions

MM- Principal investigator
JO- Collected and analysed data.
EO- Supervised the study.
AMN- Supervised the study.
EO- Supervised the study.

Data availability

Data is available upon request.

Informed consent

Not applicable. This study did not involve human participants.

Author biography

Marvin Mayambala is a student at Kampala School of Health Sciences, pursuing a diploma in Biomedical Engineering.

Jonathan Ocen is a student at Kampala School of Health Sciences, pursuing a diploma in Biomedical Engineering. Emmanuel Ogwang is a research supervisor and Multi-disciplinary Design Project I tutor at Kampala School of Health Sciences.

Alice Martha Namilo is a research supervisor and tutor of Biochemistry and Instrumental Analysis at Kampala School of Health Sciences.

Emmanuel Omongo is a research institutional supervisor at Kampala School of Health Sciences.

References

1. Al, b. (2013). *Bili blanket baby*. Retrieved from bili blanket baby: [Http://www.biliblanketbaby.com](http://www.biliblanketbaby.com)
2. Centers for Disease Control and Prevention (CDC). (2013). *Safe and Effective Phototherapy for Neonatal Jaundice*. Atlanta, GA: U.S. Department of Health and Human Services.
3. Gehealthcare. (n.d.). Retrieved from /maternal-infant_care/phototherapy/biliblanket: [Http://www3.gehealthcare.com/en/products/categories/maternal-infant_care/phototherapy/biliblanket](http://www3.gehealthcare.com/en/products/categories/maternal-infant_care/phototherapy/biliblanket) [Http://www.designthatmatters.org](http://www.designthatmatters.org)
4. Jonathan, J. (2012). *Firefly phototherapy devices*. Retrieved from design that matters:
5. Oh, W. (2003). Neonatal Hyperbilirubinemia. In J. P. Greer, J. Foerster, J. N. Lukens, G. M. Rodgers, F. Paraskevas, & B. Glader (Eds.), *Wintrobe's*

Clinical Hematology (11th ed.). Lippincott Williams & Wilkins.

6. Oksaku. (2006). *Overhead phototherapy devices*. Retrieved from Colibri Phototherapy: [Http://www.colibriphotherapy.com](http://www.colibriphotherapy.com)
7. Paul Woodgate, Luke Anthony Jardine. (2010, February). *Clinical evidence*. Retrieved from clinical evidence website: [Http://www.ncbi.nlm.nih.gov](http://www.ncbi.nlm.nih.gov)
8. Richard Idro, c. K. (2004). *Annals of tropical pediatrics 24(1), 17-24*. Retrieved from trandfonline.com
9. William Oh, J. E. (2003). *Pediatrics 112 (4) (773-774)*. Retrieved from publications.appa.org.
9. Walker, B., et al. (2012). *Design and Development of an Improved Phototherapy Blanket for the Treatment of Neonatal Jaundice*. *Journal of Medical Devices*, 6(1)

PUBLISHER DETAILS

SJC PUBLISHERS COMPANY LIMITED



Category: Non Government & Non profit Organisation

Contact: +256 775 434 261 (WhatsApp)

Email: info@sjpublisher.org or studentsjournal2020@gmail.com

Website: <https://sjpublisher.org>

Location: Scholar's Summit Nakigalala, P. O. Box 701432, Entebbe Uganda, East Africa