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Jaundice Detection System Using Physiological Characteristics

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Jaundice is the abnormal accumulation of Bilirubin in the blood, constant checking of their content level in the blood of new born children is vital as going for Anti-natal because its effect is dangerous and irreversible. At the moment, the standard method to determining the concentration of bilirubin in neonates is Laboratory Blood Test (TSB) test and this method can be traumatic for babies due to the constant blood extraction. Our goal in this research is to use hybridized machine learning techniques to develop a jaundice detection system using all the possible physiological characteristics or symptoms. The developed jaundice detection system is capable of detecting the presence of jaundice in neonate non-invasively, it also has a 0.07% standard error coefficient and a Percentage Value of 0.001 when the outcome was compared to TSB of all Test and Validation samples.

Keywords: Bilirubin; skin; gestation age; eye colour and jaundice.

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1. INTRODUCTION

Jaundice is a common abnormality seen in newly born babies within few days after their birth. Over 70 percent of new born children are clinical jaundice infected. Jaundice is a bilirubin substance disease. Bilirubin is a waste product formed during a natural process that breaks down the oxygen-carrying components in blood, hemoglobin, and myoglobin McDonagh et al. [1]. The hemoglobin breakdown occurs mainly in the liver Tenhunen et al. [2], and the resulting bilirubin waste product is toxic to certain neurons.

For newly born children, the presence of bilirubin is not a problem but excess of it becomes a problem because the liver at that stage is not strong enough to properly excrete it when needed and when the bilirubin is not excreted at certain level per body rate, it be becomes toxic. The excess bilirubin seeps out of the blood vessels into fatty body tissue, often discoloring skin, eye and sometimes the finger tips Samar et al. [3]. A population studies of jaundice in 2010 performed by Vinod et al. [4] across about 184 countries evaluated gives a scope of about one hundred and fourteen thousand (114,000) infant deaths and 75,000 children growing up with brain dysfunction (kernicterus) that could have been avoided would not have been if jaundice is properly treated. Furthermore, jaundice was discovered to be one out of the three highly rated death causing diseases among new born children of developing countries. It was stated that appropriate jaundice detection technologies are urgently needed and most of the hospitals providing neonatal intensive care across the world sees the illness as a silent instigator of quiet a no of death in infants.

Some physiological characteristics like skin colour, gestation period, eye colour, birth weight of the child, and many others. The Yellowness of the skin, eye, finger tips, and premature delivery of babies and reduced weight of a baby as a result of excess bilirubin is a major attributed of jaundice. Visual examinations have been used to screen patients and are still important in clinical situations, doctors and midwives uses it for physical examination to diagnose jaundice. Visual features are however, subjective to the observer, and objectively quantifiable methods to support optical diagnosis are frequently used in the medical community. A blood sample can be analyzed to precisely determine the exact bilirubin concentration of a patient, total serum bilirubin (TSB) for short, but requires equipment and is expensive. A lot of scientist like Sorrentino [5] are looking into the development of facilities that can solve medical related problems such as physical looks, the rate of heartbeat check, blood pressure level etc. As this researchers increases in their quest day in and day out, the consumers looks forward to a more efficient and less expensive products. Most users look forward to gargets that are less expensive, less time consuming, but would produce an accurate output.

This research used a colour separation module that was trained with over 1000 images gotten from about 150 children sampled from different places across the globe. The images were taken in the presence of white light to avoid light reflection on the image. The vital information according to the table 1 were also used as a basics of our final assumption. The back, chest and facial view images of each all children were collected respectively at every point and at four different angles each. The overall software was tested to have a high level of accuracy when validated with outcomes gotten from a blood test.

2. RELATED WORKS

Giovanna et al. [6] brought an electronic device that was able to state if a baby would need a laboratory test (TSB) Jaundice detection or not. Gagan et al. [7] did a research that look at the relationship between the total Serum bilirubin (TSB) and the transcutaneous bilirubinometer outcomes in the absence of a phototherapy section already on going on the baby. But Samar, et al., 2009 looked at a study that was made to show that transcutaneous bilirubinometer should be used to detect severe hyperbilirubinemia at its early stage.

Yu-Hsun et al. [8] researched on the importance of using JM-103 in Taiwanese children. But the device gave a more accurate result at bilirubin level 9.4 mg / dl. Brad et al. [9] proof the transcutaneous bilirubinometer of discovering the risk of hyper bilirubinemia. Kudavelly et al. [10] had designed a simpler method with promising accuracy. Kudavelly method used two specific wavelengths at 455 nm and 575 nm in absorption spectrophotometry. The application of spectrophotometer is to evaluate the absorbance peaks of the prepared solutions.

In 2013, another device was introduced by Vinod et al. [4] the device rely on Multi-wavelength spectral reflectance analysis. The reason that prompt his study was earlier discharged children that possesses the risk of hyperbilirubinemia. Ali

et al. [11] developed a technique that uses optical technology in other to detect jaundice. The philosophy he disclosed as light absorption of oxy hemoglobin at various wavelengths was applied by implementing two colours of LED lights, blue and green. A blue LED light is placed above the infant in other to serve as a source of light that will determine the level of concentration of bilirubin and a green LED light which will indicate the reference point to discriminate the difference of bilirubin and hemoglobin. The light will be reflected on the infant's skin and their rays will interact with different molecular tissues, then a photodiode will absorb the reflected light for further investigation. But their studies had a limitation of inaccurate outcome at some point above 14mg/dl of the children's jaundice level.

3. PHYSIOLOGICAL CHARACTERISTICS

3.1 Skin

The yellowish discoloration of the skin forms a major part of our basics in this research for jaundice detection. Due to the absorption of green and blue light by bilirubin, it displays a yellow colour underneath the skin. These absorption properties are today used to estimate bilirubin concentration via skin reflectance measurements Ali et al. [11].

3.2 Eye

The high concentration of the bilirubin content in the blood of a baby if not excreted can be seen in the eyes also, the colour of the eye gradually turn yellowish as the bilirubin level increases and this gradually leads to conjugated bilirubin which is popularly known as jaundice El-Beshbishi et al (2009), Gartnar, et al. [12].

3.3 Gestation Age

During gestation period, as a child grows inside the womb, the placenta gets rid of unconjugated bilirubin off a fetus. Because of this, the bilirubin conjugating enzymes are actively shut off during the pregnancy Maisels et al. [13]. However, the enzymes need time to become fully active. For babies born premature, the liver need more time before it can fully take responsibility and this can result in a rise in the bilirubin level.

3.4 Weight

Children with low birth weight, Glucose 6 Phosphate Dehydrogenase (G6PD) deficiency were also at high risk of having the illness. This was the conclusion of Joseph et al. [14] after examining 272 babies of age 1 – 30 days old born between June 2009 and June 2010 daily for evidence of jaundice in a health care facility in Delta state, Nigeria.

3.4 Age of the Neonate

Brits, Adendorff, Huisamen, Beukes, Botha, Herbst & Joubert 2018, stated thus, jaundice might not have physical signs to make it easily detectable on the first day of delivery but may gradually develop within 48 hours after delivery.

4. JAUNDICE DETECTOR DESIGN

4.1 Architectural Structure of the Newly Designed Jaundice Detector

The architecture of the jaundice detector includes a colour clustering module, a colour separation/ filtration module, a colour code generation module, an accumulator that stores the Jaundice codes generated and later the codes generated is compared with the jaundice code the system was modeled with to give the right estimation of the bilirubin level. The architectural diagram is given in Fig. 1. The research methodology used is Object Oriented Programming (OOP), Python programming language was used for back end programming, JavaScript was used for the web design and MySQL data base was used for data collection and storage.

4.2 Algorithm of the Developed Jaundice Detector

Step 0: Start
Step 1: Load form to insert test details
Step 2: Include colour separation file
Step 3: Include database connection
Step 4: Initialise accumulator
Step 5: initialise jaundice colours
Step 6: Post-test details
Step 7: Upload pictures
Step 9: Remove white and black spots
Step 10: Separate colours
Step 11: Convert colours to codes
Step 12 Increase accumulator by 1 for every colour code found in the jaundice colours
Step 13: Give bilirubin levels based on the accumulator value
Step 14: Give Remarks/Recommendations based on the Bilirubin levels
Step 15: Add results and patient data to database
Step 16: End

Table 1. Recommendation summary

Bilirubin Level	Postnatal Age	Remark	Recommendation	Colour Codes Present in the Image
< 2 mg / dl	Above 2.8kg	Very low bilirubin level	Frequent feeding and exposure to indirect sunlight at home. Then do a retest of bilirubin levels to make sure it has not gotten worse.	1
< 10 mg / dl	2.5kg-4.0	Low bilirubin level 1	1. Frequent feedings and exposure to indirect sunlight at home for neonate above 2.8kg. 2. Test the baby bilirubin levels again to make sure it has not gotten worse. 3. Baby may be admitted for more proper observation for neonate bellow 3.0kg having Sepsis	2 to 3
10 to 14 mg / dl	2.5kg-4.0	Low bilirubin level 2	1. Frequent feedings and exposure to indirect sunlight at home for neonate above 2.8kg. 2. Test the baby bilirubin levels again to make sure it has not gotten worse. 3. Baby may be admitted for more proper observation for neonate bellow 3.0kg.	4 to 5
15 to 16 mg / dl	Below 3kg	High bilirubin level 1	Baby below 3kg needs to be admitted for a phototherapy section and observation	6 to 7
17 to 19 mg / dl	Below 3kg	High bilirubin level 2	Baby above 4 days and are below 3kg needs to be admitted for phototherapy and observation and may require exchange blood transfusion not just phototherapy.	8
>20mg / dl	Below 3kg	Very high bilirubin level	An Emergency! Baby above 4 days and are below 3kg needs to be admitted for phototherapy, observation and exchange blood transfusion.	> 8

(Source: Ekereke & Asagba, 2020) [17]

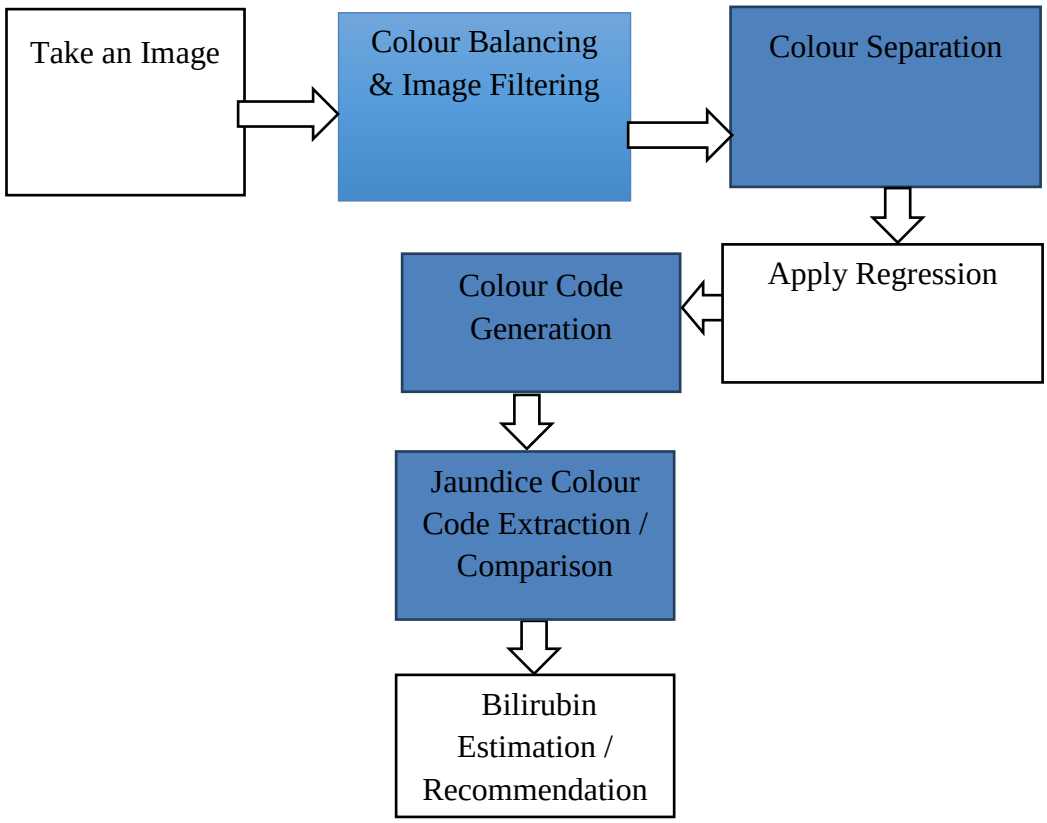

Fig. 1. Architecture of the Developed Jaundice Detector

Once an image together with the metadata history of a child is received by the jaundice detector, colour clustering and image filtration is done on the image, and the needed part is separated from the unneeded image after which regression is applied to the resultant image, then colour code(s) is generated from the image. The colour code generated is then compared with the standard jaundice colour codes used in training and if any jaundice colour code is detected, the accumulator will be incremented by one. At the end, the accumulator will give the total no of jaundice colour code present in the image and the estimated bilirubin level with respect to Table 1. At this point, all other physiological characteristics will be put into consideration and the final bilirubin estimation is given together with the recommendation.

Medical conditions such as sepsis, respiratory distress, or cardiac or circulatory disease were not present in these infants used.

5. RESULTS AND DISCUSSION

The outcome from our jaundice detection system is with a very high level of accuracy, and it can be relied upon. For example, research shows that most babies with issues of Jaundice have gestation periods of less than 37 weeks or have weight problems at birth. The findings from test result conforms this theory to be true as shown in the result given in Fig. 2. A look at the parameters and the results/recommendations is a clear confirmation of that fact. From the graph in Fig. 3, both results are quite similar with a 0.07% standard error as shown in Table 3.

Fig. 3 shows a graphical representation of the result giving in Table 2 compared to the blood sample bilirubin test result gotten from laboratory test (TSB measurements) done on same children plotted against weight. From the graph both results are quite similar with a 0.07% standard error as shown in Table 4.

Table 2. Bilirubin Level Estimations from TSB and Developed Jaundice Detector Software

Weight (mg)	**1.8**	**1.9**	**2.0**	**2.3**	**2.8**	**2.8**	**2.8**	**3.1**
Developed Jaundice Detector Software Result (mg / dl)	10	16	14	10	10	19	5	12
Standard TSB Result (mg / dl)	10	16	15	10	10	18	5	12

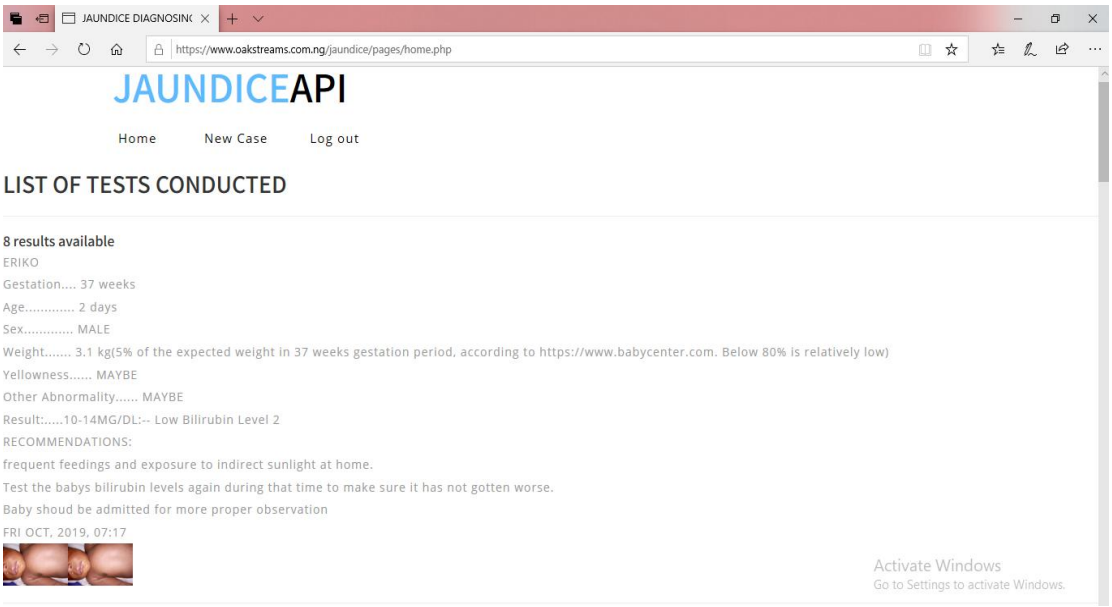

Fig. 2. Sample of result from our Jaundice Detector

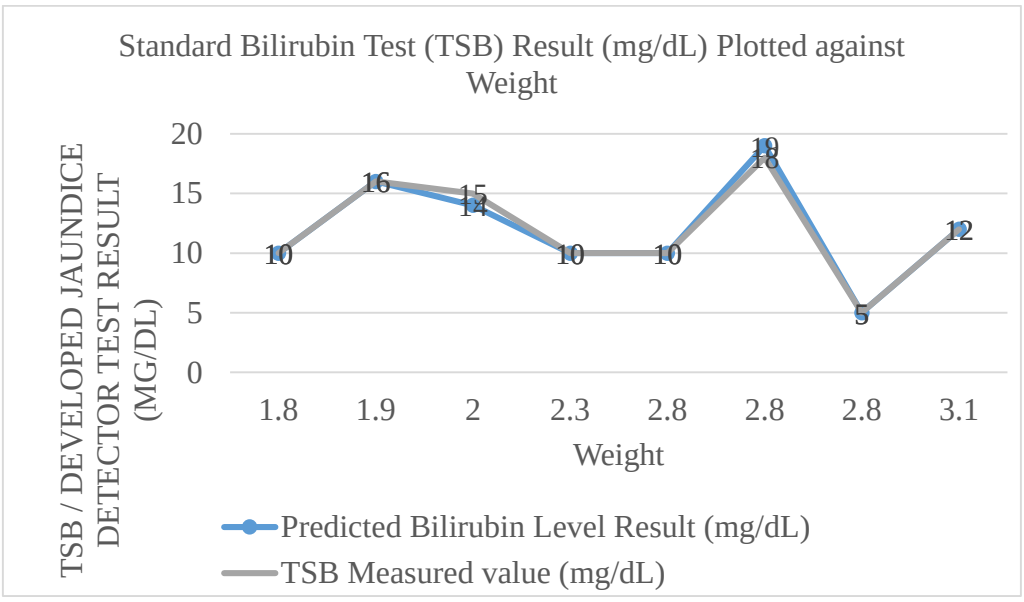

Fig. 3. Graph showing plot of both result against weight of the neonates

Fig. 3 shows an outcome of all children with high bilirubin level to have a weight of less than 3.0mg and just one out of the three neonates with weight above 3.0mg was seen to be to be high. This is a clear confirmation of the National Institute for Health and Care Excellence 2010 and the standard Treatment Guidelines and Essential Medicine List Report. Helen et al., 2011 stated in their research that children with low birth weight are at high risk of falling ill of jaundice after they examined 272 babies between the ages of 1 – 30 days old.

The duration of the gestational period can also contribute to the jaundice rise in a neonate, this is as a result of not fully developed liver to aid in the excretion of excess bilirubin produced in the baby's blood. Fig. 4 confirms this statement in Nelson's textbook of pediatrics. Shu-Shu-Chiung et al. [15] also stated in their research that the risk of developing hyperbiliribin is directly proportional to low gestational age. Thomas et al., (2000) plotted a regression, plot that revealed that pre-term neonates are at high risk of developing hyperbiliribin. Folorunso et al., (2015)

in their study in which 232 neonates were examined for jaundice case also concluded that gestational age was a clear factor causing neonatal jaundice.

In Fig. 5, it is clear that the age of a child after birth is of high importance to the ease in jaundice detection. This is in line with the study of Brits et al. [16] which stated thus, jaundice might not have physical signs to make it easily detectable on the first day of delivery but many gradually develop within 48 hours after delivery. The outcome of the graph of Fig 5 shows that at the first day of delivery, which was seen to be day zero on the graph most of the children did not reflect a high level of jaundice but as the day increases their jaundice level might increase for those with recessive cases, that is the more reason why the constant monitoring of newborns is required even after some days of the delivery.

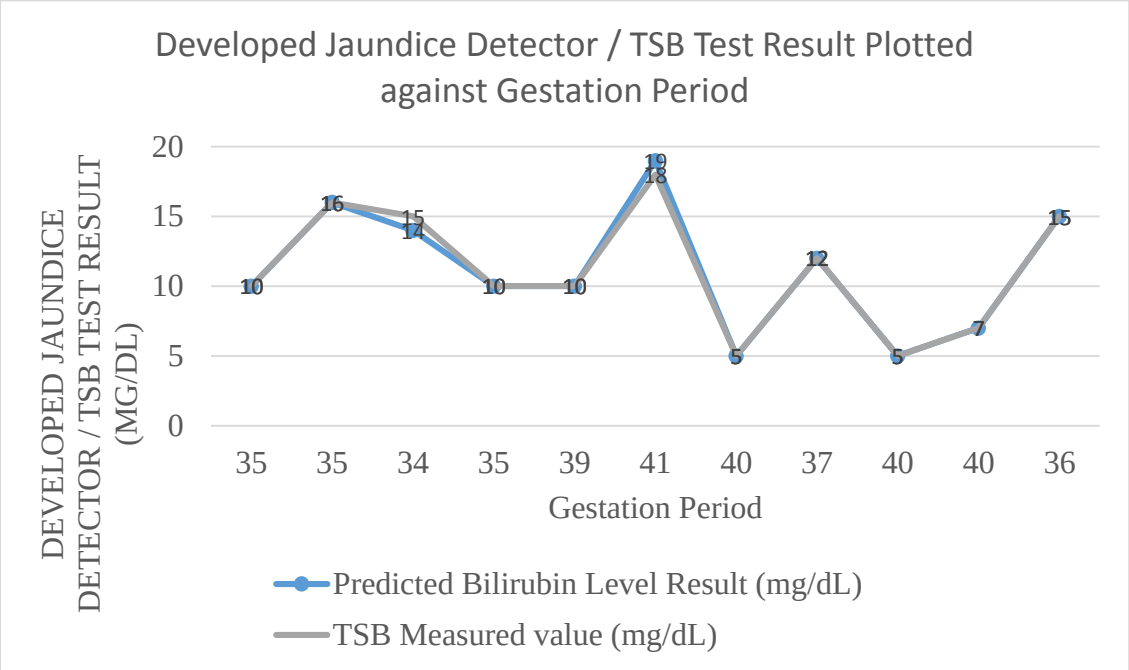

Fig. 4. Developed Jaundice Detector / TSB test Result Plotted against Gestation Period

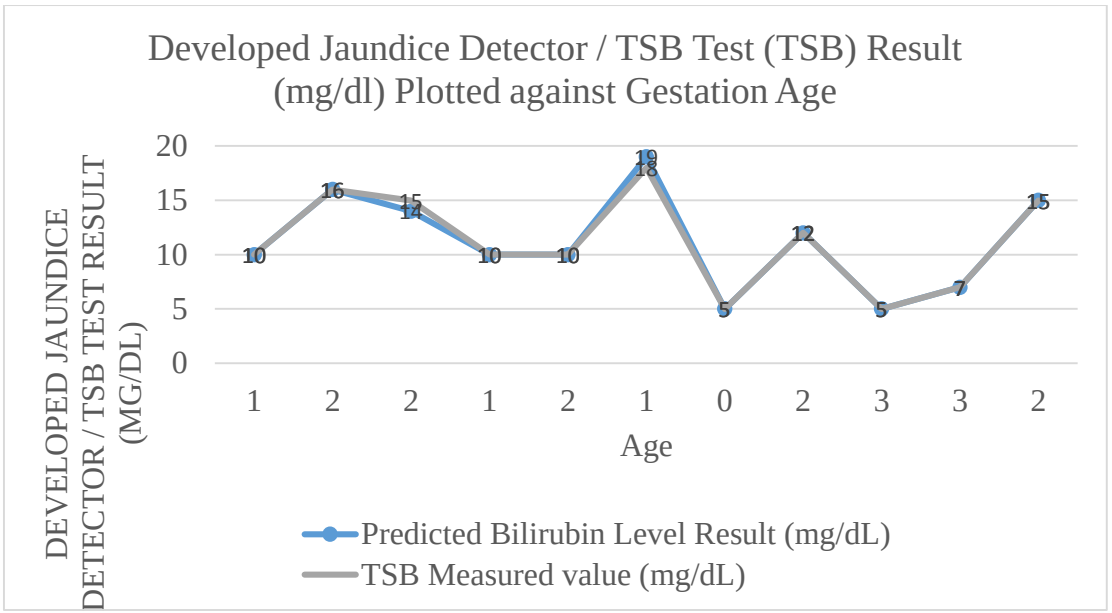

Fig. 5. Developed Jaundice Detector / TSB Test (TSB) Result (mg/dl) Plotted against Gestation Age

Table 3. General table of the both results (TSB and Developed Jaundice Detector Software Prediction)

Sex	F	M	M	M	M	F	F	M	F	F	F
Gestation Period	35	35	34	35	39	41	40	37	40	40	36
Postnatal Age(Days)	1	2	2	1	2	1	0	2	3	3	2
New Developed Jaundice Detector Software Result (mg / dl)	10	16	14	10	10	19	5	12	5	7	15
Standard TSB Result (mg / dl)	10	16	15	10	10	18	5	12	5	7	15

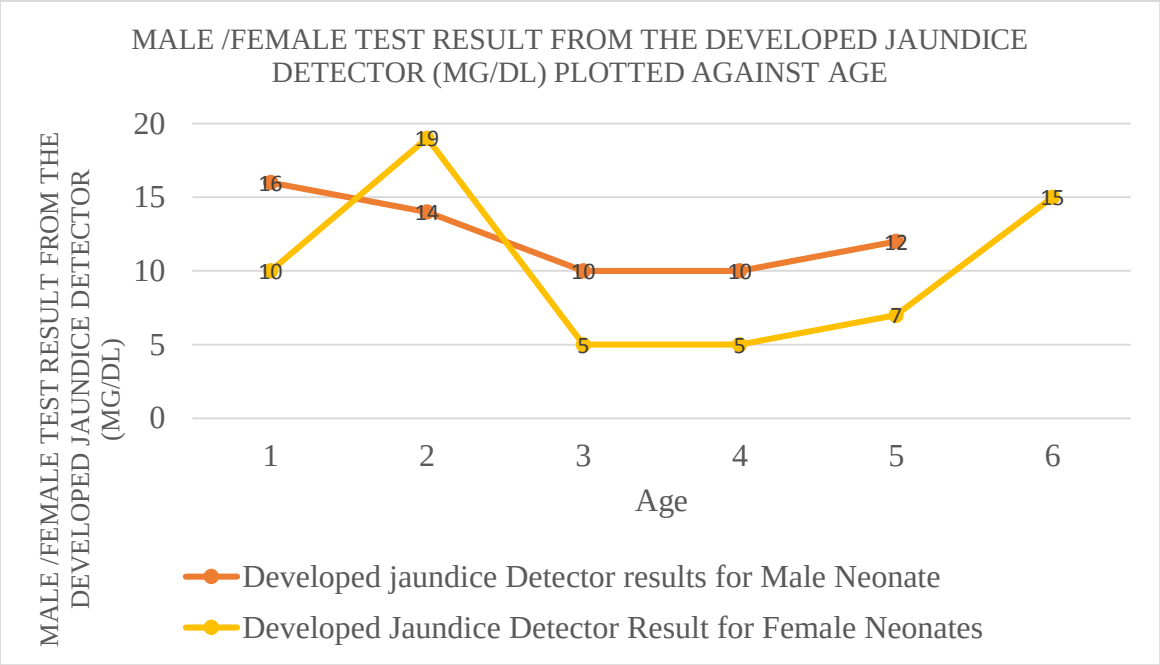

Fig. 6. Male /female test result from the developed jaundice detector (mg/dl) plotted against age

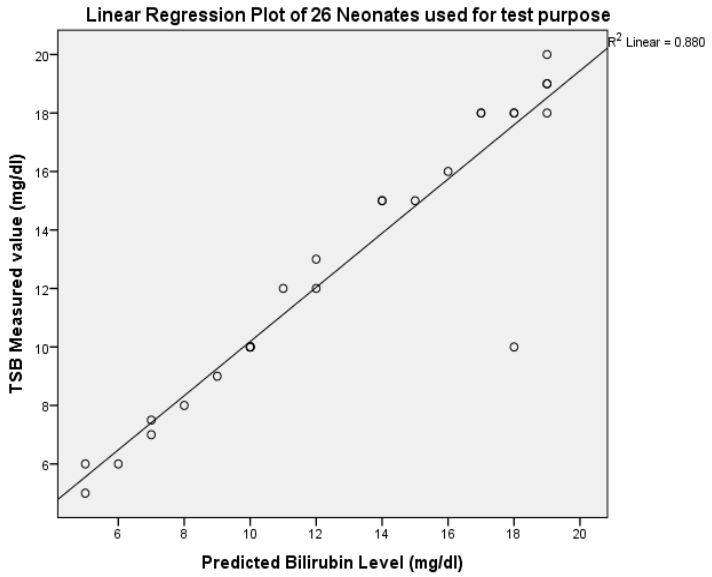

Fig. 7. Linear Regression Plot of 26 Neonates used for Testing Purpose

Table 4. Table showing the standard error and the standard coefficient

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	.657	.954		.689	.497
VAR00002	.950	.070	.938	13.521	.001

Fig. 6 shows that the male children are at high risk of developing jaundice after birth and this confirms the result from Louise et al., 2005 who analyzed a data set of 869 children that went for phototherapy and came up with the 1:1.3 of boys to girls. Kolawale et al. [18] also proves this facts during his research and concluded that though the number of female children delivered were more during the period of his work but the number of male children diagnosed to have the jaundice were a little higher still. This result also confirms the Hamid et al. [19] who also has a higher number of male jaundice neonate than female, from our graph though more of male children develop jaundice but the severe case is mostly associated with the female neonates. Their research stated thus, the high rate of jaundice in male neonates is as a result of the presence of a lower enzyme level of the activities of G6PD in the male babies than in female babies.

The Standard Error and Probability value of estimation using a regression plot is shown in Table 4.

Table 4 gives the standard Error to be 0.070, while the Probability value is 0.001. This confirms that the outcome of the developed software can be highly relied upon. Furthermore, from Figure 7, all the outcomes are visible very close to the regression line this also confirms that the variables are normally distributed.

6. CONCLUSION

The yellow skin discoloration and some other physiological characteristics as mentioned can be attributed to high concentration of bilirubin which is a situation known as jaundice. These attributes have been combined to form the building blocks to which our jaundice detector is built. The jaundice detector is capable of detecting the presence of jaundice non-invasively at all levels and gives the necessary recommendation with a very high level of accuracy. The correctness of its outcome was evaluated by comparing it with the standard TSB result of all the neonates used for testing.

In conclusion, our jaundice detector is a solution and can be implemented for use by hospitals and homes as a screening alternative for the detection of Jaundice as early detection will prompt early intervention and improve neonatal survival especially in low income countries.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. McDonagh AF, Lightner DA. Like a shrivelled blood orange-bilirubin, jaundice, and phototherapy. Journal of Pediatrics. 1985;75(3):443–455.
2. Tenhunen R, Marver HS, Schmid R. Microsomal heme oxygenase characterization of the enzyme. Journal of Biological Chemistry. 1969;244 (23):6388–6394.
3. Samar NE, Karen ES, Amin AM, John RP. Hyperbilirubinemia and transcutaneous bilirubinometry. Clinical Chemistry. 2009;55(7):1280-1287.
4. Vinod KB, Glenn RG, Saul A, BK, Chris D, Lois HJ. Noninvasive measurement of total serum bilirubin in a multiracial pre-discharge newborn population to assess the risk of severe hyperbilirubinemia. The American Academy of Pediatrics. 2013;106:1-9.
5. Sorrentino G, Fumagalli M, Milani S, Cortinovis I, Zorz A, Cavallaro G, et al. The impact of automatic devices for capillary blood collection on efficiency and pain response in newborns: A randomized controlled trial. International Jornal Nursing Students 2017;72:24-29. DOI:10.1016/j.ijnurstu.2017.04.001
6. Giovanna B. Non-invasive bilirubinometry in neonatal jaundice. Semin Neonatol. 2002;7:129-133.
7. Gagan M. Transcutaneous bilirubinometer in assessment of neonatal jaundice in Northern India. Indian Pediatrics. 2005;42; 41- 45

8. Yu-Hsun C, Wu-Shiun H, Hung-Chieh C, Chien-Yi C, Jing-Yi W, Po-Nien T. The effectiveness of a noninvasive transcutaneous bilirubin meter in reducing the need for blood sampling in taiwanese neonates. Clinical Neonatalogy. 2006;13(2) 60-63.
9. Brad SK, Ann T, Paula JS, Walter JC. **"**Evaluation of the bilichek noninvasive bilirubin analyzer for prediction of serum bilirubin and risk of hyperbilirubinemia. American Journal Clinical Pathology. 2008;130:976-982.
10. Kudavelly S, Keswarpu P, Balakrishnan S. A simple and accurate method for estimating bilirubin from blood. IEEE Int. Instrum. Meas. Technol. Conf. 2011; 1– 4.
11. Ali N, Muji SZM, Joret A, Amirulah R, Podari N, Dol RNF. Optical technique for jaundice detection. ARPN J. Eng. and Appl. Sci. 2015;9929–9933.
12. Gartnar LM, Lee KS, Moscioni AD. Effect of Milk Feeding on Intestinal Bilirubin Absorption in the Rat. Journal Pediatr. 2003;103:467 – 471.
13. Maisels MJ, Kring E. Transcutaneous bilirubin levels in the first 96 hours in a normal newborn population of >=35 weeks' gestation. Pediatrics. 2006;117(4):1169–1173.
14. Joseph AE, Helen EC, John EA. Prevalence of neonatal jaundice on central Hospital, Warri, Delta State, Nigeria. Int. Journal of Health Research. 2011;4(3):123 – 126.
15. Shu-Chiung C, Heather HP, Shudhakar E, Christine NB. Management of hyperbilirubinemia in Newborns: Measuring performance by using a benchmarking Model. Pediatrics. 2003;112(6): 1264-1273. DOI:10.1542/peds.112.6.1264
16. Brits H, Adendorff J, Huisamen D, Beukes D, Botha K, Herbst H, Joubert G. The prevalence of neonatal jaundice and risk factors in healthy term neonates at National District. Journal of Trop Pediatrics. 2018;58:150-55.
17. Ekereke L, Asagba PO. Jaundice colour separation using machine learning technique with PHP programming language tools. International Journal of Innovative Science and Research Technology. 2020;5(6). ISSN No:-2456-2165.
18. Kolawole SE, Obuceh HO, Okandeji BOR. Prevalence of Neonatal Jaundice in Baptist community Hospital in Delta State Nigeria. Journal of Public Health and Epidemiology. 2015;8(5):87–90.
19. Hamid MH, Chisti AL, Mumtaz A, Hussain S, Maqbool S. Bilirubin Estimation in Neonatal Jaundice. A Comparative study between Auto Analyzer (Diazo Method and Bilirubinometer (Direct Photometeric Method). Pak. Paediatric Journal. 2003;27: 68–73.

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