DLSU RESEARCH CONGRESS 2020
"Building Resilient, Innovative, and Sustainable Societies"
June 17-19, 2020

Project NEON: Development of A Neonatal Transport Incubator

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Abstract: Natural and man-made calamities can happen anytime and the worst moment if it happens when a baby has just been delivered. During these times access to a medical facility becomes more difficult and delay of access can be life-threatening to the newborn. Infants born prematurely before 37 weeks of the gestation period and those born full term but underweight require an environment similar to that of the womb in order to cope until the desired weight is achieved. Premature and underweight babies born in the house, lying-in clinic or even in evacuation areas need to be transported immediately to a hospital and be given medical attention, but without enough medical support during transport, it can lead to complications such as breathing and temperature control problems. Excessive vibration can also be life threatening and may lead to shaken baby syndrome. To address these issues an alternative and cost-effective transport incubator was designed that utilizes locally-available products. This study was limited to the usage of a scale figure of a baby for testing, monitors the temperature and humidity inside the incubator, and reduces the vibrations during transport. These conditions were measured using a thermostat, hygrometer, and an accelerometer application called VibSensor, respectively. Trials were done using a tricycle as transport being the most common mode of transportation in a local community. Results showed that the device was able to maintain temperature and humidity within acceptable range as well as reduce intensity of vibrations relative to not using the incubator. It is concluded that the device is a feasible alternative to modern neonatal transport incubators.

Keywords: Transport Incubator, Premature, Neonate, controlled environment

1.INTRODUCTION

Infants born before 37 weeks of the gestation period are known as preterm or premature babies. Preterm babies require surroundings exactly similar to that of the mother's womb in order to cope with the external environment. (Lawn, Davidge, Paul, Xylander, Johnson, Costello, Kinney, Segre, & Molyneux, 2012). The infant has several disadvantages in terms of thermal regulation as it has little capability to conserve heat. (Mittal, H., Mathew, L., & Gupta, A., 2015).

During difficult times such as during calamities, Filipino families coped by reducing spending, primarily on medicine and education. This also results to rising infant mortality (Shikha Jha, 2018).

Premature birth can cause possible complications but Incubators have been proven to reduce neonatal mortality rates. However, this type of service may not be immediately received by

infants due to unavailability of an incubator in nearby health centers and the lack of these devices in hospitals.

Caution should also be observed when transporting the baby, as the child may experience excessive vibrations that may lead to abusive head trauma which is caused by forceful shaking of the infant leading to hemorrhages, hematomas and other impairments to the baby (Mian, M., Shah, J., Dalpiaz, A., Schwamb, R., Miao, Y., Warren,K., & Khan, S., 2015).

In this research a low-cost transport incubator was developed as the holding place of the baby until they reach the nearest hospital with an advanced incubator. The term NEON is a play on the word neonate. Its color, being neon, also symbolizes that there is an "emergency". It will consist of three main components - temperature regulation, humidity control, and vibration reduction. This product will not be tested on babies.

2. METHODOLOGY

2.1. Vibration Reduction

The vibrations that will be received by the child should be reduced in order for it to avoid having abusive head trauma. For the base, a light-weight 16" x 11" wooden container with a depth of 7" was used. The basis for choosing these dimensions was the size of a typical month-old neonate (about 20") and assuming that a typical neonate after birth is smaller than the average (Villines, 2019). To ensure that the child is in a reliable enclosure that is capable of reducing vibrations a mattress was placed in the incubator and a transparent plastic was used as the top cover of the incubator to protect from dust while still allowing it to be visually monitored.

The incubator was fastened onto the baby carrier with heavy duty velcro bands to prevent the incubator from slipping out. The whole incubator is then attached to a baby carrier that is worn by the parent. The body of the parent also acts as a vibration damper.

In order to measure the vibrations, a phone with an application called VibSensor was placed inside the incubator. A series of trials were conducted in a tricycle as it is one of the most common means of transport. Three trials following the same route along Tunasan, Muntinlupa to San Pedro, Laguna were made and each trial ranged from around 40-50 minutes. Shaken baby syndrome occurs at around 30G which is expected to be much more than what will be observed in a tricycle trial but any vibrations evident should nevertheless be minimized. (Lewis, 2016).

The three trials were labeled as Standard, First Run, and Second Run. For the Standard, the cell phone running the Vibsensor app was placed inside the base and was not held by the mother. For the First and Second Run, the cell phone was strapped to the baby using a velcro band and was placed inside the incubator. The incubator was then attached to the baby carrier to provide stability. Because of the orientation of the baby, only the acceleration in the x and y-axes were compared as these movements may contribute to the shaken baby syndrome.

2.2. Temperature Regulation and Humidity Control.

Several trials were conducted to test the humidity and temperature using a hygrometer. The test lasted for 60 minutes with each data of a minute being tabulated on an excel spreadsheet. A graph was constructed in order to emphasize the changes brought by the humidifier on the temperature and humidity.

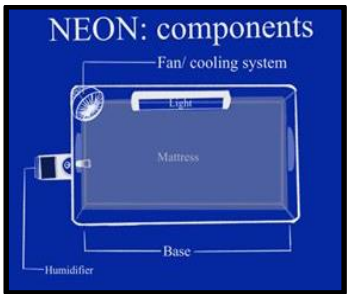

Figure 2. Layout of Electronic Components (Top View).

3. RESULTS AND DISCUSSION

The transport neonatal incubator will be discussed based on three parts - System Design and Production Costs, Vibration Reduction, Temperature Regulation and Humidity Control. Other parameters of an infant incubator such as airflow regulation and sound suppression was not included in the study due to the limitations of the current prototype.

3.1. System Design and Production Costs

The incubator is made out of a bamboo basket, with a foam mattress inside for the comfort of the baby. The humidifier, and fan, are also located within the unit for ventilation. The incubator is placed in an adjustable carrier, with side straps fit for the mother's comfort, and attached using velcro bands.

NEON was designed this way so that it would come off as convenient for consumers and easy to use and transport. Another note to consider is that most mothers do not rely on transport incubators that temporarily separate them from their child. Studies show that maternal separation anxiety is present. Once the child gets separated from the mother for a short time, the mother experiences sadness, worry, and guilt during that time until the child returns (Hock & Schirtzinger, 1992).

As compared to current neonatal incubators, which costs around ₱680,000-₱2,000,000, initial prototype of NEON costs only approximately ₱5000.

Figure 3.1. Side view of the incubator w/o carrier

Figure 3.2 Top view of incubator w/o carrier.

Figure 3.3. Front view

Left Side *Right Side*

Figure 3.4. Side View with carrier.

3.2. Vibration Reduction

Past studies revealed that the increased morbidity and mortality are the effects of excess vibrations with brain injuries and becomes the common cause of death of infants (Blaxter, L., Yeo, M., McNally, D., Crowe, J., Henry, C., Hill, S., Mansfield, N., Leslie, A., & Sharkey, D.,2016).

Data collection was done through road testing and the usage of Vib Sensor. The values in the standard are gathered when no modifications were made to the incubator while the values gathered for the first and second run contain the vibration reduction tools. Afterwards, the mean, standard deviation, maximum and minimum values, and the percentage difference between the mean of the standard and the experimental values were obtained.

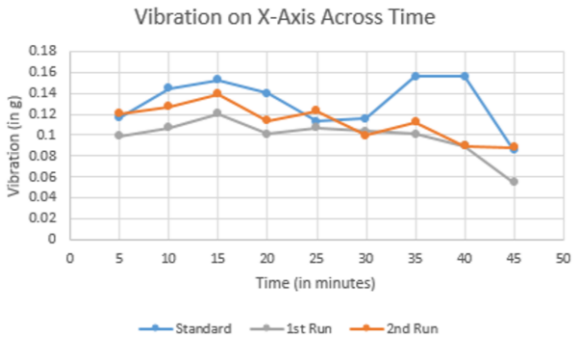

Figure 3.5 Vibration on X-axis Across Time Graph.

Figure 3.5 shows the vibration levels along the x-axis experienced for the whole ride. These values are obtained by applying the concept of the simple moving average, wherein the average of all the data points given a period of time, in this case, every 5 minutes, is taken as the representative of the whole interval. Simple moving average consolidates data points into fewer points to see the trend more clearly. After doing so, the standard, first run, and second run are then compared to each other using a line graph. This method was also applied to the vibration levels on the Y-axis.

Table 3.1 shows the acceleration, in terms of m/s^2 and g, and how a neonate may perceive it. In Table 3.2, the mean, in both X and Y axes for all runs, belongs to around "fairly uncomfortable" to "uncomfortable" perceptions while both the minimum and maximum values are on the "extremely uncomfortable" level. Notably, the standard deviation is quite high which means that the vibration levels are spread out over a wider range.

Table 3.1 Accelerations and their perceptions.

Acceleration		**Perception**
m/s²	**g**	
< 0.315	< 0.032	Not uncomfortable
0.315-0.63	0.032-0.064	A little uncomfortable
0.5-1	0.051-0.102	Fairly uncomfortable
0.8-1.6	0.082-0.163	Uncomfortable
1.25-2.5	0.127-0.255	Very uncomfortable
> 2.0	> 0.204	Extremely uncomfortable

Note. Adapted from *Vibration Issues of Neonatal Incubators During In-Hospital Transport*, by Jake Browning, David Walding, Jack Klasen and Yadin David (2008).

In Table 3.3, it can be seen that the trials which had vibration reduction tools show that there was a definite decrease of vibration based on the obtained mean (average). A decrease in the standard deviation was also evident for both x and y-axes which means that the vibration levels are less spread out than it previously was. Furthermore, the maximum and minimum value had an increase in the percentage that may have been affected by other factors such as the driver's speed. It can be inferred that the vibration reduction tools were effective in reducing the vibration levels.

Table 3.2. Mean, Standard Deviation, and Maximum and Minimum Values experienced along X and Y axes.

VIBRATION (in g)						
	STANDARD		1ST RUN		2ND RUN	
	X	Y	X	Y	X	Y
MEAN	0.13	0.07	0.10	0.07	0.11	0.08
SD	0.19	0.11	0.15	0.10	0.16	0.11
MAXIMUM	4.92	1.15	2.94	1.30	5.03	1.77
MINIMUM	-1.03	-0.85	-1.25	-2.23	-0.89	-2.23

Table 3.3 Percentage Difference of Trials Compared to Standard.

	1ST RUN		2ND RUN	
	X	Y	X	Y
MEAN	-25.17%	-8.46%	-14.17%	-0.05%
SD	-24.79%	-3.22%	-13.20%	1.42%
MAXIMUM	-40.22%	13.05%	2.28%	53.99%
MINIMUM	22.23%	163%	-12.99%	163.12%

3.3. Temperature Regulation and Humidity Control.

The standards for the NICU state that the thermal condition of the environment within the incubator should range from (27.7 - 30 °C) so that the infant body temperature can maintain to 36.4 °C and the relative humidity should be within 30–60%. Thomas, K. A., Magbalot, A., Shinabarger, K., Mokhnach, L., Anderson, M., Diercks, K., Millar, A., Thorngate,L., Walker, W., Dilback, N., & Berkan, M., 2010).

In this device, humidity and temperature regulation was done using a mini USB humidier controlled by a thermostat control board that automatically turns on and off the power supply depend on the measured temperature. Based on the results of the test, it can be seen in Figure 3.6 that humidity was high in the first 15 mins but improved and stabilized around 51%, well within the acceptable range of 30-60%.

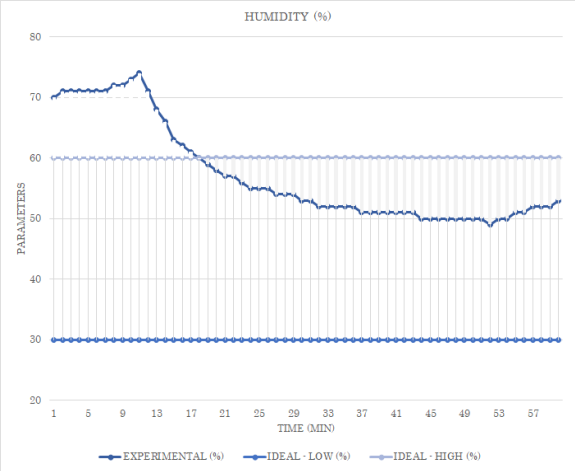

Figure 3.6 Relative Humidity across Time.

Meanwhile in Figure 3.7, the temperature stabilized at around 29°C, well within the acceptable range of around 27.7 - 30°C (Bird, 2020). The graph also shows an inverse relationship between the two; humidity decreases as the temperature increases.

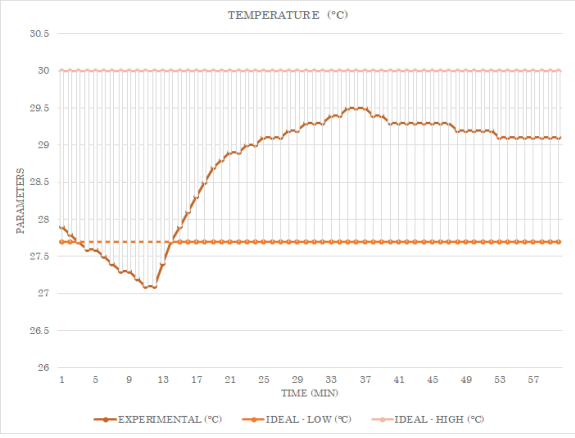

Figure 3.7. Temperature across Time.

This test was considered a very vital part of the process as ensuring that the final product can prevent the baby's body temperature to fluctuate above or below their normal temperature.

4. CONCLUSIONS

Project NEON has proven to be effective in reducing the vibration and maintaining proper temperature and humidity as it performs within the industry standards of incubators. Nonetheless, it is recommended that for the further development of this study, that the temperature-regulation system be improved by using a more efficient cooling system. Regulation of airflow and sound suppression should also be considered and UV Lighting for phototherapy to avoid jaundice should also be used.

5. ACKNOWLEDGEMENTS

The researchers would like to thank the Institute of Biomedical Engineering and Health Technologies (IBEHT) for the technical assistance to the group. They would also like to thank Ms. Candice Perez for her contribution.

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