Neural Network Based Weight Prediction System for Bariatric Patients

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Abstract – Obesity has become an epidemic condition in Sri Lanka as well as around the world. It is proven beyond doubt that Bariatric Surgery (BS) is the most effective option in treating morbid obesity patients, whose Body Mass Index (BMI) is greater than 40.0. After undergoing surgery, it is required to monitor a patient's weight for eighteen months until they reach a healthy weight that falls within the normal BMI range (18.5-24.9). This study has analysed records of bariatric patients registered at Colombo South Teaching Hospital, Kalubowila under three surgery types. Records show that due to the inability of tracking their weight loss throughout the post-surgery period and lack of continuous assessment after BS, majority of patients have lost their track of weight before reaching the eighteenth month. Therefore, some patients have to go through the same operation more than once, which creates a threat to their lives. This study aims to remotely track pre-and post-surgery bariatric patients and allow them to keep track of their weight loss until they achieve their expected weight using a web-based weight prediction system based on artificial neural networks. To predict the final weight bariatric patients might get after the surgery, pre-surgery and post-surgery data are taken as inputs. Mainly three predictions are aimed to be given as the outputs; namely pre-surgery, post-surgery and monthly weight. Machine learning algorithms like artificial neural networks provide an average of 85% accuracy in predicting the weight until the patient achieves the expected result in the final month.

***Keywords**: Bariatric Surgery (BS), Body Mass Index (BMI), obesity, morbid obesity, telemedicine, neural networks, machine learning, artificial intelligence*

I. INTRODUCTION

According to the World Health Organization recent statistics the 5th most risk factor that causes death is obesity(Obregón, 2020). When referring to the statistics 4.72 million deaths have been recorded under this obesity factor and about 1.9 billion of adults were considered to be overweight("Obesity and overweight," 2016.).

It is clear that reducing the obesity and guiding the morbid obesity Patients to fall back into the healthy BMI range should be addressed in the current world. In Sri Lanka prevalence of overweight and obesity is 37% and 15.8% respectively, which is a considerate amount and a prevailing issue in Sri Lankan Health sector.(Somasundaram et al., 2019). Risk conferred by obesity can be reduced by sustained weight loss, but this is difficult in a majority. Bariatric surgery (BS) has proven to provide an excellent answer to this problem.(Bulugahapitiya and Muthukuda, 2014). It is clinically and scientifically proven that bariatric surgery is one of the most effective long term solutions in treating morbid obesity patients (BMI>40) with weight reduction.(Wijetunga et al., 2019).

The only Government Hospital that provide the Bariatric Surgery in Sri Lanka is the Colombo South Kalubowila Teaching Hospital. Number bariatric operation types are performed globally. Among all the operation types performed worldwide only 3 main types of bariatric surgeries are performed in srilanka according to the Sri Lankan body type.

I. Laparoscopic Roux on Y Gastric bypass
II. ILaparoscopic Sleeve Gastrectomy / Vertical
Sleeve Gastrectomy

III. Laparoscopic Mini-Gastric Bypass / Single Anastomotic Gastric Bypass

All type of surgeries are performed 100% Laparoscopic (Key hole) manner by the medical team with only very small incisions on the abdomen to reduce the weight of patients.

After the bariatric surgery, every patient has to go through a separate continuous assessment for a period of eighteen months. It should also be accompanied by a yearly visit to the doctor until they achieve the desired result which is considered as a healthy BMI (18.5—24.9)(Zhang et al., 2015). The current follow up process of each BS patient is done manually and there is no any common platform for both Bariatric patients and Medical Officers to track the weight loss. Due to a lack of attention during this period and other physical and mental facts, results may change and Patients might have to undergo the same process from the beginning. Figure 1. clearly shows at the end of 18 months, most of the patients have lost a considerable amount of weight but haven't achieved the goal of a healthy BMI.

Moreover, a lesser number of data available of postoperation BMI values show that majority of the patients have lost their track of recording at the end of 18 months. These patterns explain that lack of follow up and tracking patient's weight throughout the 18 months period is one of the major problems in the current system. This is the reason for not getting the expected results at the end of 18 months.

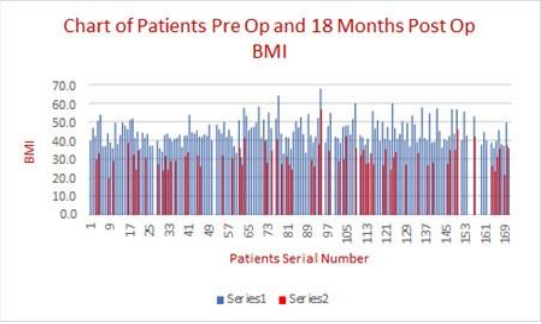

Figure 1. Histogram of 170 patient's pre-operational and postoperational (after 18 months) BMI values. Source: Colombo South Teaching Hospital, Kalubowila

Due to this current manual system there is no way of getting an idea about the final weight and the weight they can achieve after the surgery. To overcome this issues in the current manual system in Kalubowila Teaching Hospital Developing this system shows a positive path towards the Bariatric Patients and Medical Officers. This application can offer a number of important advantages to both patients and medical officers. The application is designed to give three achievable weight predictions for patient's.

I. Ability to predict the final weight(18 month) of patient before undergoing the surgery.
II. Ability to Predict the final weight of Patient (18 month) after undergoing the surgery.
III. Ability to predict the weight of patients for each clinical visit
    i. 2 weeks
    ii. 1month
    iii. 3months
    iv. 6months
    v. 9months
    vi. 12months
    vii. 15months
    viii. 18months-final month

In all cases prediction is done by involving artificial neural network which is one of the deep learning technique. Also, in this system it can produce an achievable plan to attain a healthy BMI in 18 months. If there is a difference in the actual weight and the desired weight, this system is able to detect it and guide them to follow the correct path to achieve the desired weight. It will minimize the number of patients undergoing the surgery again. Moreover, this provide physical and mental support to patients to succeed in their weight loss journey. Also, it allows patients to add health assessment records on their own and update the medical officers.

This system provides telemedicine support in any pandemic situation too.Also Automated system will help the medical officers identify the patients with completed health assessments to conduct the BS. They will receive a proper track of their patient who has/has not completed their

assessments, which will provide a better understanding of the patient's weight loss journey. We have analyzed records of more than 500 bariatric patients registered at Colombo South Teaching Hospital, Kalubowila. This application will also provide direction to get into expected weight during the post-surgery period. This will prevent them from repeating the BS again.

II. LITERATURE REVIEW

Bariatric surgery is done for patients suffering from morbid obesity (BMI over 40.0) within Sri Lanka. After undergoing the surgery, it is needed to keep assessment of patients for 18 months until they reach to a healthy weight level, which falls on the healthy BMI range. These patients need more support after undergoing surgery to continue to lose further weight or to maintain a healthy weight that falls on the normal BMI range, which is the main target of undergoing the Bariatric Surgery.(Bulugahapitiya and Muthukuda, 2014.) Remotely tracking the physical activity of such patients and predicting their weight may give health professionals a more clear image of the activities of these patients and provide more personalized support.(Wijetunga et al., 2019)

A. *Current System*

Currently, there are applications in other countries for bariatric patients but in Sri Lanka, there are no systems or a mobile application designed to automate this bariatric process and track bariatric patients' weight. When considering the current manual system there are mainly two parts as pre and post-surgery,every patient should undergo four medical assessments in the pre surgery part as Endocrine, Respiratory, Endoscopy, Nutrition so after completing them pre-operative assessments can be recorded before the surgery will take place.(Mundi et al., 2015) The post-operative management. Two weeks after the operation undergoes , each and every patient should visit the endocrine clinic in the hospital with 8 main reports.

1. TSH report
2. Lipid Profile
3. Fasting Blood sugar
4. HbA1c Report
5. Se Ionized Ca ^2+
6. Se Protein/ALT/AST
7. 25-Hydroxy Vit D level
8. Full blood Count.

will be measured at the clinic.(DeMaria, 2007) Every 4 weeks,3 months,6 months,9 months,12 months,15 months ,18 months after the operation date should take the above reports and should visit the hospital. At the end of 18 months, patients should get to their expected weight. In some cases if they were unable to achieve that, weight the patient has to go through an alternative way to get into the expected weight, so these patients have to go through the Bariatric surgery again.

B. *Existing Systems*

Currently there are applications designed to track the physical activity of the bariatric patients after the surgery. And when it comes to weight loss most of the apps focus on the exercises, meal plans, Nutrition and Water Tracking, diets and Bariatric Specific Recipes for them to lose or continue their weight.(Murphy et al., 2020) However, these systems are unable to predict the weight of the patient after all, which is the main functionality of our planned system.

Few researches have been foused on predicting the weight of BS patients using different of methods. A few of researches obtainable in the literature are explained below.

When predicting the weight after the BS (Abu Dayyeh et al., 2011) has proposed a system which focuses on the Weight regain after Roux-en-Y gastric bypass (RYGB) and elavuated evaluated whether gastrojejunal stoma diameter is a risk factor for weight regain after RYGB using ML. RYGB is one of the surgeries out of BS performed in Sri Lanka. They looked at data from patients who were sent to a tertiary care bariatric facility for upper endoscopy following RYGB over the course of four years. The relationship between the gastrojejunal stoma diameter and weight recovery was investigated using linear regression analysis. To construct a prediction

rule for weight increase following RYGB, they have used a logistic regression model including clinical and endoscopic characteristics. 59% of the 165 participants in their research exhibited significant weight gain while 41% did not. The used a 7- point scoring system that included the gastrojejunal stoma diameter, race, and percentage of maximal body weight lost after RYGB to develop a simple prediction rule for weight regain after RYGB; a cut-off score of 4 or more points had an area under receiver operating characteristic curve of 0.76 and a positive predictive value of 75%.

ANN to Predict Long-term weight loss success following the BS using pre operative and short term data was discussed by ("Neural Networks to Predict Long-term Bariatric Surgery Outcomes," 2017.). They have trained and tested eight ANN that relies on liner regression to predict the long term weight status one year after the surgery. Which outputs a single weight prediction. Here they have considered data of patients eight different surgery types.

C. *Weight Prediction Systems*

Here our aim is to give a whole plan about how the weight loss will occur during the 18 months. When predicting weight of the patients it is needed to identify the most appropriate technology to predict the weight. Several researches have reviewd number of weight prediction systems using different emerging technologies, among them few of the researches have discussed as follows.

(Babajide et al., 2020) and the team have discussed a Machine Learning Approach to Short-Term Body Weight Prediction in a Dietary Intervention Program.This program was carried out for 10 weeks to get the data. Machine Learning models that were utilized was Linear regression, Support vector machine (SVM), Random Forest (RF), Artificial Neural Networks (ANN). Among all these models RF was able to provide the highest accuracy level of 96% when comparing to other models. Since RF is much better than other machine learning algorithms due to its ability to handle small data sets. able to generate a minimal error.

Emmanuel O. Salawu Et.al and the group have developed a ANN based weight prediction system to predict body weight of rabbits and they focus on the same breed and same age group of rabbits. ANN model was trained with 75% of the data sets from the same age groups, and the model's effectiveness was measured with 25% of the data sets.(Salawu et al., 2014) Five predictor variables were used viz, breed, sex, heart girth, body length and height at wither as input variables and body weight was considered as dependent variable from the model. In terms of predicting body weight, ANN models are found to be more efficient than Machine Learning models. We do understand, however, that fitting an ANN model needs more computing resources than fitting a conventional Machine Learning model.

As a result, according to the above analysis, ANN are the matching technology to get accurate results when predicting body weight by considering other similar factors. Deep learning approach to link weight prediction which was reviewd by (Hou and Holder, 2017) usin R model which is an ANN model created to provide a deep learning approach to link weight prediction problem. When predicting the weight model R shows an accuracy of 73 percent when comparing to stochastic block model and its derivates.

When reviewing all the above researches it is concluded that ANN models are more powerful than Machine Learning models in predicting body weight. Nonetheless, we recognize that fitting an ANN model requires more computation resources than fitting a traditional Machine Learning model. Therefore, according to the above study to predict the body weight by considering other related factors ANN is the most matching technology to get the accurate results.

Table 1. Analysis of Existing Systems

Existing System	Technology	Accuracy	Limitations
Weight regain after Roux-en-Y gastric bypass (RYGB)	-Linear Regression, -Logical Regression	75%	-Focused on only on e type of surgery. -165 data records
ANN to Predict Long-term weight loss success	-ANN	85%	only one type of output was predicted.
Deep learning approach to link weight prediction	-ANN - Model R	73%	Comparetively low Accuracy
ANN based weight prediction system to predict body weight of rabbits	-ANN -Feed forward network	71%	needed more computing resources than fitting a conventional Machine Learning model.
A Machine Learning Approach to ShortTerm Body Weight Prediction in a Dietary Interventio n Program	-ANN -Linear regression -Support vector machine - Random Forest	96%	minimum mean absolute percentage error produced from RF in predicting body weightloss is still high.

III. METHODOLOGY

A. Dataset

Bariatric Surgery Patients dataset consist of 500 Patients clinical data who have registerd at the Kalubita teaching hospital. The data set is composed of 361 clinical record columns which is taken before the surgery and after the surgery. To get the most accurate results most appropriate clinical data are selected for each prediction. For the Pre surgery weight prediction only the pre surgery clinical data records are considered and for the post surgery prediction both the pre and post clinical records are taken into consideration. To get the most accurate results only the most relevant clinical data are taken while the personal details of each patient is not taken and their personal data are not considered since each patient is addressed by their serial number to ensure their privacy.

B. Approach

The users of this system are Bariatric Patients and Medical Officers. ANN module and the Web system are the main two parts of the system where the Medical officers gets to add,edit or remove records while the Bariatric Patients can only view their records and progress which is the predicted weight. The input data will be used to train the ANN. After training the network, it will produce a model which can be used to predict the weight of each Bariatric Patient. This model can then be deployed into a Web system so that Bariatric patients who are registered at Kalubovila Teaching Hospital and the Medical Officers when monitoring Patients can use it. Figure 3 is a schematic illustration of this process.

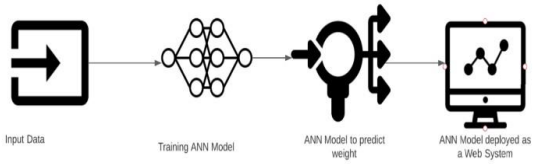

Figure 2. Process of Implementing the Application
Source: Author

A. Technology Adopted

As this sytem composed of mainly two modules as the Web application and the ANN module are implemented using several technologies and programming Languages. The ANN was developed using Python in Jupyter notebook.Web application has been implemented using selected programming languages Html, CSS, JavaScript and Python in android studio. For the database firebase is used. The technology that suits for the system development should be decided by considering the domain and the requirements for the system.

It is important to identify most appropriate technological methodologies to satisfy the functional requirements and the non-functional requirements of the system in the system development procedure.

B.Deep Learning Modules of the proposed system

Artificial intelligence includes ANN, which are mathematical representations of the human brain. ANN have the ability to "learn" in the same way that the human brain does. ANN is represented by a sequence of neurons arranged in layers. Weights are used to connect each neuron in a layer to other neurons. The direction and strength of the connection between neurons are described by the weight values. The information supplied to the ANN is represented by an input neuron. Our brains receive information from our senses in a similar way. A prediction generated after synthesis within the ANN is represented by an output neuron. This is related to how our brain makes a decision based on information received through our senses.

Under three ANN predictions weight has been predicted.The first ANN relied on solely 19 pre-operative inputs of surgery types 1 to 3. A value output which is the final weight of a patient after 18months was predicted using 70 percent of the data. The model was independently tested on 30 percent of the data, which was not used for model development.

The second ANN again relied solely 101 pre-operative measurements and post operative measurements to predict the 18 month weight after undergoing the surgery. Similar to the first model, A value output which is the final weight of a patient after 18months was predicted using 80 percent of the data. The model was independently tested on 20 percent of the data, which was not used for model development. The model was independently tested on the remaining portion of the data not applied for model development.

Finally The third ANN used pre-operative and postoperative inputs of surgery types 1 to 3, depending on the last clinical month the patient have visited to predict the next upcoming month weight. A value output was predicted for each monthly weight prediction using 80:20 percent of data in training and testing.

The Bariatric patients dataset is trained using a ANN from scratch. The data set was divided into two parts as training set and testing set in the ratio of 70:30,80:20 and 80:20 in each three predictions.

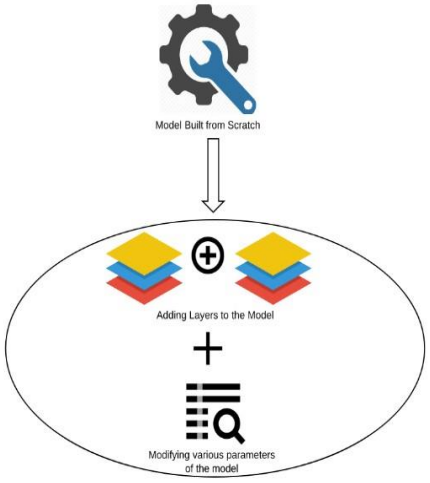

Figure 3. Design of the model built from scratch
Source: Author

Figure 4 shows a graphical visualization of how new layers are added to the initial Source and how the parameters are modified experimentally to obtain the best model.

All the data has been preprocessed in each three predictions to a get a cleansed dataset. In all three weight predictions we have used feed forward algorithm beacause it gives an output without going in loops. The RELU activation function is used because it directly outputs if it is positive otherwise it will output zero. Four ANN are used in predicting the weight in each prediction. The network was trained for 200 times as the data was sent 200 times through the network to obtain models. After completing the training part testing is done.

The model was created via transfer learning and fine-tuning, as seen in the diagram above. The pre-trained network is subjected to transfer learning first, followed by fine-tuning, as illustrated in the diagram. The final model is obtained after both of these steps are completed, as indicated.

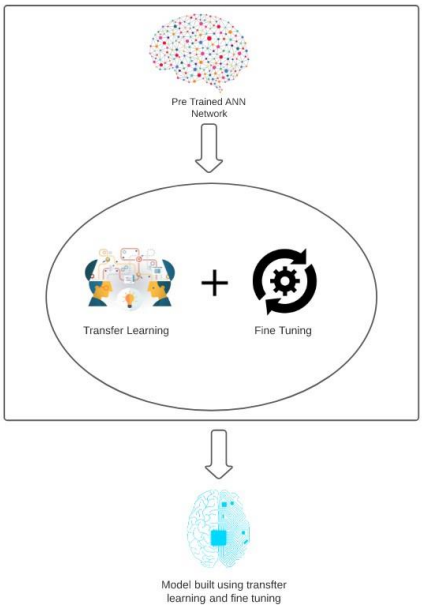

Figure 4. Design of the Model using Transfer Learning and Fine-Tuning Source: Author

IV.RESULT AND DISCUSSION

The overall weight prediction presented by this work adheres to an experimental procedure. First the Bariatric patients dataset is trained using a ANN from scratch. The final accuracies are then compared to use the best model in the web application. The comparisons of the 3 models are shown in the table 2 below.

Table 2. Analysis of System Results.

ANN	Input Neurons	Output Neurons	Accuracy	Training & Testing
Pre operative	19	Final weight	83%	70:30
Post operative	101	Final weight	85%	80:20
Monthly	Depending on the month	Monthly weight	75%	80:20

Classification of weight loss success using only preoperative markers ANN can correctly identify patients result in successful weight loss after 18 months from surgery with 85 percent accuracy. In post operative predition 83 percent of success rate and monthly weight prediction accuracy of 75 percent. Here the highest accuracy is achived from the post operative ANN which is consist of more inputs and highest records of patients which can increase the accuracy.

When selecting the most suitable model among the above three architecture not only the better accuracy is considered. Other non-functional requirements like efficiency, size, compatibility and power consumption are also taken into consideration. Non-functional requirements which are considered can be taken to later examination when fine tuning the system to get the highest accuracy by changing the batch size.

V. CONCLUSION AND FUTURE WORK

In conclusion, this study shows that after a BS, the main aim of achieving the desired weight in a healthy BMI range of patients does not improve significantly. The lack of postsurgery follow-up and the insufficient physical activity and mental health complications of patients are several reasons why most patients struggle to achieve optimal weight loss after undergoing BS.(Buchwald et al., 2004) This study further show, developing effective and non-invasive remote technologies to help track the physical activity and weight loss of patients may allow medical officers to support patients who are not on the correct track. Also by continuously tracking the patients' weight loss and predicting the weight, will minimize the number of patients undergoing BS again. Mainly this will help to achieve a healthy BMI range, which is the ultimate goal. Although the technologies of web apps have not yet reached that point of growth, the current study offers suggestions to enhance the usability of the mobile applications along with ensuring the secure level of the system.

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ACKNOWLEDGMENT

We would like to acknowledge Prof. WGDTK Wijerathne and Mr.AAGK Abeysinghe who helped us with giving Bariatric Surgery background knowledge to conduct this research successfully.

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