Predicting Hand Grip Strength of Hand Held Grass Cutter Workers: Neural Network vs Regression

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Abstract

Exposure to hand transmitted vibration caused disability in term of hand grip strength force among hand held grass cutter workers. \textbf{Objective:} This current study develop prediction model of independent and dependent variable that induce to loss of grip strength using non-linear neural network and linear multiple regression prediction approach for both hands. Linear and non-linear approach was used the direct least square and activation sigmoid function, respectively. \textbf{Method:} 204 hand held grass cutter worker have been selected as the subject study due hand arm vibration exposure during operation which is significant to loss hand grip strength. The independent variables consist of age, height, weight, working experience and estimated vibration exposure per day while hand grip strength was selected as the dependent variables. \textbf{Result:} The performance indexes of regression are better fit for neural network compared to multiple regressions with 0.017 (right hand grip) and 0.066 (left hand grip) differences, respectively. The mean square error also stated near to “0” for non-linear compared to linear techniques. \textbf{Conclusion:} It concludes that the neural network model is superior to the linear model. However, best architecture of neural network algorithm could be implemented to increase performance index, hence produce the accurate prediction model for hand grip strength among grass cutter workers.

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Selection and Peer-review under responsibility of the Scientific Committee of MIMEC2015

Keywords: Hand Grip Strength ; Hand Arm Vibration ; Neural Network ; Multiple Regression
1. Introduction

Loss of hand grip strength disability for both hands is a major occupational disease concern in hand transmitted vibration exposure activities for all types of vibrating equipment. This disability causes reduced quality and productivity, low job satisfaction, increased medical cost and impaired worker safety and health [1]. Hand grip strength disorder caused by vibration exposure is a significant risk factor associated with hand-arm vibration syndrome (HAVS). For instance, working activities that required hand held machine used strength of the worker both hands to reduce hand grip strength. The physical hazard contacted directly from the source of vibration which is the machine and transmitted to workers hand as a receiver, respectively. In general, the work that used vibration equipment should be eliminated or substitute with less vibration risk exposure [2]. However, the normal practice implemented in agriculture sector to reduce the hazard was followed the administration control either by minimize the working time or increase the number of workers to complete the activity.

Despite many studies have been done in the field of comparison prediction model development from non-linear neural network (NN) and linear regression, up to the author knowledge, there are no study have been done to investigate the dependent and independent variables which contribute to loss of hand grip strength among hand held grass cutter workers. Although, study about the linear and nonlinear modeling of adult Malaysian population’s hand grip strength was done [3], however this study only was focusing on the age, weight and height as input variable without including working experience involving vibrating equipment. Meanwhile, study on prediction model using NN to classified industrial job induce to low back disorder [4], design the ergonomics school furniture [5], human body posture [6] and blasting vibration at copper mine [7]. All those research depicts that the ability of NN in determine the best prediction model in engineering application.

This research aims the development of prediction model based on the NN and regression approach based on the age, height, weight, working experience and estimated hand vibration, \( A(8) \) as the independent variables while the hand grip strength for both hand as the dependent variables, respectively. Further, these two different approach was compared its mean square error (MSE) and Regression (R) value. The analyze data was obtained from HAVS case study among hand held grass cutter worker in south of peninsular Malaysia.

2. Neural Network & Multiple Regression

NN is one type of artificial intelligent contain a mathematics model which represent a multiple interconnection processing elements in distributed adaptive system by followed the concept from real neural in human brain [4]. The ability of NN to adapt, train the input and target data produce the significant weight coefficient based on the activation function selected. Indeed, the NN normally based on the function of back propagation feed forward network. This means that the interpolation process was done for each cycle of learning network until produce the best relationship between the input and target. However, there is inconsistency of the weight produce based on the computational performance and the arrangement of input data. The NN consists of three major elements which are train, validate and test data. Each of these three major elements has their own partition (70%, 15%, 15%). On the other hand, the hidden layer (black box) which located in the middle element between the input layer and target layer composed of function which is continuous and non-linear so called multilayer perceptron (MLP). In practice, the NN learns the function mapping of a multiple set of inputs to the target and desired output [1]. Hence, this prediction model produce from learning process will be validated and tested from the random input data.

Various problems in science and engineering engage reviewing the relationship among qualitative and quantitative variables. Regression techniques is a statistical analysis which able to solve these kind of problems. In general, regression between two or more variables used ordinary least square analysis approach. There are a lot of problem identify the relation involve more than one independent variable. A multiples regression model by means a regression model which consist more than one independent variables [8]. Multiple linear regression analysis is used to explore the predictive ability of more than one independent variables on one continuous dependent measure [9]. The basic equation for multiple regression model as follows:

\[
Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \ldots + \beta_nX_n
\]  

(1)
Where: $Y$ is the dependent variables, $n$ is the number of independent variables, $X_i$ is the independent variables, $i = 0, 1, \ldots, n$, $\beta_i$ is the regression coefficient, $i = 0, 1, \ldots, n$.

3. Materials & Methods

The subject from hand held grass cutter workers subcontractor participated in the HAVS case study compromised of 204 male workers. Their age ranging from 15 to 56 years were used to represent the significant contribution to loss of hand grip strength force due to hand transmitted vibration exposure. The subject was interviewed by adopted questionnaire from vibration injury network association. Part of the questionnaire are asking about the quantitative value such as the age, weight, height and working experience in grass cutting operation. Besides that, each worker undergoes the hand grip strength test using manual dynamometer to determine the normal hand grip strength before operation. This procedure repeated 3rd times to get an average force value (kg) for both hand. Meanwhile, hand arm vibration measurements were collected on site by using human vibration meter (Larson Davis). Indeed, this objective data would be determine the estimate both hand vibration exposure per day in 8 hours, $A(8)$. Hence, the data (input – age, weight, height, working experience & estimated hand vibration exposure, $A(8)$; target – hand grip strength force for both hand) acquired from the case study will be used as the variables selected to develop the prediction model.

Conventional method to develop the prediction model using linear multiple regression approach has been selected. The data analysis was done using IBM SPSS statistics v19. The age, weight, height, working experience and estimated $A(8)$ was selected as the independent variables while hand grip strength force was selected as the dependent variables, respectively. In other hand, the prediction model was performed using 5 inputs and 1 output. Hence, left and right hand grip strength model will produce separately due to vibration exposure at right and left hand were different. The direct ordinary least square regression method and confident interval 95% level was selected in this study.

Same approach was used to analyze the data using non-linear NN. The MATLAB v8 neural network start tool was used to determine the prediction model. The NN fitting tool is able to map between a data set of numerical input and a set of numerical target or output. Inputs is a 5x204 matrix, representing statics data of 204 samples of 5 elements while target is a 1x204 matrix, representing statics data: 204 samples of 1 element, respectively. The random data were divide randomly into 3 stages which is 70% for train, 15% for validate and other 15% for test. The train model represent the network during learning and the network is adjust according to its error, the validate model used to measure network generalization while the test model provided an independent measure of network performance during and after training. Ten of hidden neurons were set as best number after try and error by means manipulating the hidden neuron number. The architecture of NN was shown in Figure 1. It is noted that 5 input of data will enter the hidden layer and train the data using non-linear activation function of Lavenberg-Marquardt back propagation (trainlm) due to its ability to learn in fast and automatically stops when generalization stop improving.

![Figure 1: Structure of NN architecture on learning set](image)

Both model able to produce MSE and R quantitative value after the analysis process done. The MSE depict average squared difference between predictions and targets while R measures the correlation between predictions and targets, respectively. Lower values of MSE are better while an R value of 1 means a close relationship. The
prediction data will be comparing with the actual data to provide performance index comparison value, hence identify which the best techniques to simulate the data obtained in future.

4. Result & Discussion

The linear multiple regression model obtained from direct least square methods for right YR and left hand grip YL are stated as:

\[
Y_R = -38.091 - 0.348X_1 + 36.879X_2 + 0.32X_3 + 0.008X_4 + 1.089X_5
\]  
(2)

\[
Y_L = -19.460 - 0.317X_1 + 26.557X_2 + 0.312X_3 + 0.002X_4 + 0.171X_5
\]  
(3)

Where \(X_1, X_2, X_3, X_4 \) and \(X_5\) represent age (years), height (m), weight (kg), working experience (months) and estimated vibration exposure per day (m/s²) respectively. Based on the both equation, the working experience depict small number of regression coefficient, due to no significant different \((p > 0.05)\) of the data collected and the standard deviation of the data is 26.672. However, working experience data is important in determining the hand grip strength due to duration of occupational hand vibration exposure. Both linear regression model produce negative constant for regression coefficient depict as -38.091 and -19.460 for right and left hand, respectively. The different of regression coefficient value for height is 10.322 consider high compare to other independent variables. Other variables shows less than 1 different of regression coefficient value between right and left hand prediction model.

The NN model was trained for 11 epochs and the qualities of fit for the both hand non-linear models are shown in Figure 2. From the prediction model produce indicated that the regression for all data set is 0.6245 and 0.5728 for the right and left hand grip strength respectively. The prediction model “output” in NN give the weight coefficient for the summation of independent variables based on the convergence of error calculation in back propagation learning system. The prediction and target value relationship for both hands consider strong since the value for all regression are more than 0.5. Although, the correlation between the predicted and target is quite normal but the value of R is higher compared to linear multiple regression method as shown in Table 1. In addition, the MSE values for linear method are higher compared to non-linear method as well due to the ability of the NN to train the data by iteration process. The ability of learning from previous or given data made the NN best application for analyze the non-normal statistically distribution data. Indeed, this finding support other research done which analyze the
performance index of predicted future data especially for epidemiological study gives non-linear approach more suitable.

Table 1. Comparison between linear and non-linear performance index based on MSE and R value for the predicted both hand grip strength

<table>
<thead>
<tr>
<th>Model</th>
<th>Mean Square Error, (MSE, %)</th>
<th>Regression, (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Multiple Regression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Hand Grip</td>
<td>75.56</td>
<td>0.608</td>
</tr>
<tr>
<td>Left Hand Grip</td>
<td>72.66</td>
<td>0.507</td>
</tr>
<tr>
<td>Non-linear neural network</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Hand Grip</td>
<td>62.07</td>
<td>0.625</td>
</tr>
<tr>
<td>Left Hand Grip</td>
<td>68.96</td>
<td>0.573</td>
</tr>
</tbody>
</table>

5. Conclusion

It can be conclude that the linear least square and non-linear neural network were able to predict the hand grip strength of workers. The major finding was shown the NN model is superior to the linear model. However, best architecture of NN algorithm could be implemented to increase performance index, hence produce the accurate prediction model for hand grip strength among grass cutter workers.

Acknowledgements

We would like to thanks the Universiti Tun Hussein Onn Malaysia (UTHM), leading highway Maintenance Company in Malaysia and National Institute of Occupational Safety & Health (NIOSH), Malaysia for their assistance support programme for the Research and Development and its Funding Projects 03.05/03/NG04_GRASSCUTTER/2014

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