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Formulating the Relationship of Mean Kicking Angle and Leg Flexibility Index for Silat Athletes Using Regression Analysis

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Abstract: Silat is one of the martial arts involving various techniques of kicking which its utilization can be related to one's flexibility. In this research paper, it is assumed that the greater the kicking angle, the greater will be the leg flexibility index. Based on this assumption, several objectives have been formulated which are first; to modify the existing flexibility index formula to suit with the current needs, to formulate linear equations based on regression analysis and finally to analyze the developed formula based on residual plot analysis. Twenty participants from two different backgrounds; silat athlete (n=10) and non-athletes (n=10) were recruited to perform three trials of kicking in order to obtain their average kicking angle whereas their leg flexibility index were calculated using the proposed modified formula. Both of these parameters were used as the inputs for finding the relationship between mean kicking angle and leg flexibility index in the form of linear equation. The regression analysis was performed using Excel and the main findings revealed the accuracy based on R^2 value were above 0.9 for both models with residual values were approximate to zero, indicated high quality of relationship equation models generated from the silat and non-silat athletes. Future works will include the validation experiment using sit and reach test for evaluating the performance of the obtained models as well as machine learning implementation using Matlab for producing prediction models.

Keywords: Kicking Angle, Leg Flexibility Index, Regression Analysis, Residual Plot

1. Introduction

Biomechanics is the study of the application of mechanics to biological systems such as human systems. In sports, injury prevention and rehabilitation act as part of the main goal which we can ultimately assumed that uninjured athlete will perform much better than the injured athlete. The

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importance of biomechanics can be seen by the improvement of athlete's technique. Therefore, biomechanics can be implemented in two ways by which trainers and coaches can use their knowledge of mechanics to fix an athlete's behaviour to improve the quality of results, and biomechanics experts can also use a brand new method to execute athletes sporting skills [1].The biomechanical factors instrumental of an axis kick's effectiveness are based on three dimensions of the kick which are total goal height, kicking leg inertia, and also kicking foot speed. Besides, the height at which an athlete can perform an attack is determined by the anthropometry that includes the fighter's body height, leg length as well as flexibility [2].

Silat is one of the martial arts of self-defense practiced in Malaysia by the Malay ethnics and its efficiency requires the movement part of the human body including hands and legs. Kicking is one of the actions, where it is performed using both legs to protect and attack during the performances [3]. Performing a front kick involves movement of knee and foot raising to the desired height which requires the leg approaching the target and it can be used for attacking as well as self-defending. It is much powerful than a punch because the legs carry a large mass as compared to the hands [4].

It is assumed that the greater the kicking angles of an athlete, the greater the leg flexibility index they have. However, to author's knowledge, there is no study that have been conducted to establish the relationship between kicking angle and the leg flexibility index. Previously, the authors had developed a specific tool to record the front kicking angle by using flex sensor and the data can be monitored wirelessly with the aid of Internet of Things (IoT) for tracking the performance of silat athlete [5]. Using the same developed tool as in [5], this research was conducted with the aim to formulate the linear equation based on the assumption; the greater the kicking angles, the greater the leg flexibility index.

Thus, a regression analysis has been considered to achieve this aim. In general, regression analysis has been widely used to evaluate the relationships between one independent variable and one dependent variable [6]. It can indicate whether the independent variables have a significant relationship with the dependent variables and how the relative strength of different independent variables' effects on a dependent variables as well as it can be used to make predictions using the formula created from the regression analysis. On the other hand, residual plot is important in order to evaluate the obtained formula. The predicted values of flexibility index can be obtained by replacing the value of *x* through the equation. Once the predicted values are obtained, residual plot can be constructed using those residual values attained from the difference of both observed (actual) and predicted values.

Based on the problem statement discussed above, three objectives had been formulated which were first: to modify the existing flexibility index formula to suit with the current needs, second: to formulate linear equations based on regression analysis and finally, to analyze the developed formula based on residual plot analysis. Due to COVID-19 restriction, only twenty subjects were managed to be recruited (Silat athlete=10 and non-Silat athlete=10), whereas the kicking angle was recorded using the tool developed previously and thus, these two points represent the scopes of this project.

2. Methods

2.1 Modifying Flexibility Index Formula

An intrinsic property of the body tissues which specifies the range of motion that can be attained without injury in a joint or joint group is known as flexibility [7]. In this study, the relationship between the flexibility index and the kicking angle was being considered. The flexibility index is dimensionless and it can be obtained by dividing the maximum range of kick with the body height of the subject as shown in the Eq. 1 [8].

$$Flexibility\ index = \frac{maximum\ range\ of\ kick\ (cm)}{height\ of\ subject\ (cm)} \qquad \text{Eq. 1}$$

Eq.1 stated that the flexibility index can be obtained by dividing the maximum range of kick by height of subject. However, this formula is not suitable to be used directly in this study. The reason is simply because the developed tool used to record the mean kicking angle is placed at the hip region between pelvis and upper thigh bone as previously shown in [5] so that when the subject is performing their front kicking, the bended flex sensor that attached at the developed tool in [5] can provide the corresponding degrees of kicking. As a matter of fact, every person has different length of leg despite having the same height (because of different length of torso) and therefore, the length of leg has been proposed to replace the height of subject. Therefore, instead of taking the overall height of participant, the most suitable parameter is by using the true leg length.

Figure 1 shows the proposed measurement of true leg length based on human leg anatomy. The measurement of true leg length is taken from the Anterior Superior Iliac Spine (ASIS) until the medial malleolus [9]. Medial malleolus is one of the bony prominence which located on the inner side of ankle formed by the lower end of tibia. Thus, the new leg flexibility index can be obtained by dividing the maximum range of kick with the true leg length and the modified formula based on this assumption is presented in Eq. 2 where the leg length of the subject is used rather than using the height of the subject.

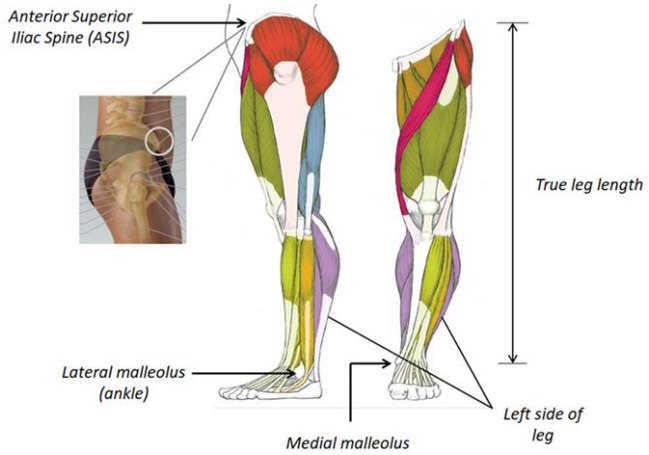


Figure 1 : Measurement of true leg length

$$Leg\ flexibility\ index = \frac{maximum\ range\ of\ kick\ (cm)}{length\ of\ leg\ (cm)} \qquad \text{Eq. 2}$$

2.2 Experimental Procedures

As mentioned beforehand, the mean kicking angle was recorded using the previously developed tool. For clarification, a brief explanation on this device is given here. Figure 2 shows the schematic diagram of the developed device which consist of flex sensor, I^2C LCD Display and NodeMCU ESP8266 microcontroller. The NodeMCU was implemented as it could provide wireless connection between the microcontroller and the Blynk app. A simple graphical user interface was developed in Blynk app that able to execute three main tasks which are: i. accept the input values of maximum range of kick and true leg length; ii. display kicking angle and iii. display the true leg flexibility index. Then, a pouch bag was modified to place in the LCD and the microcontroller. Later, the subjects were required to wear the pouch bag with the flex sensor attached on the subject's thigh (dominant leg) before they were allowed to perform three trials of front kicking action.

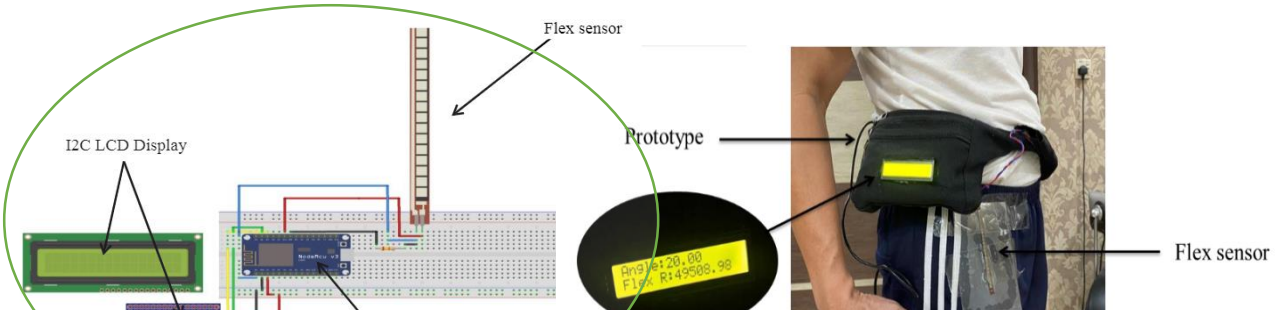
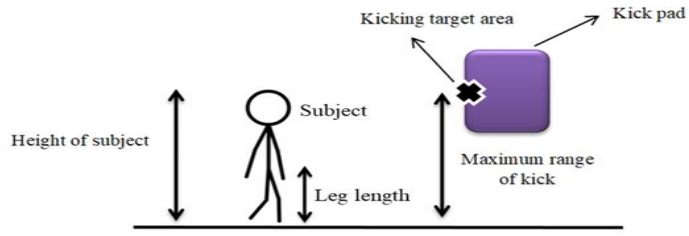
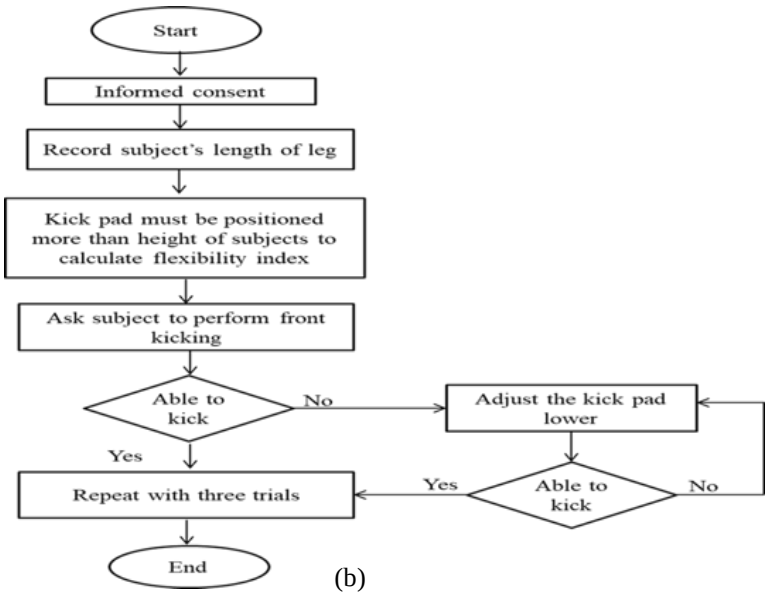


Figure 2 : IoT-based kicking angle prototype previously developed by [5]

Figure 3(a) represents the initial setup of kicking experiment [10]. Briefly, the kick pad was initially positioned higher than the height of the subject to obtain the maximum range of kick. Meanwhile, Figure 3(b) represents the flow chart of experimental procedures starting from getting the subject consent until performing the three trials of front kicking action. The leg flexibility index was automatically calculated by inserting these two inputs into the Blynk app: i. the value of maximum range of kick that the subject is able to kick and ii. the value of the measured true leg length. The angle degree of kicking and the leg flexibility index were viewable on the LCD as well as on the Blynk app each time the kicking action was performed. An average value of kicking angle from the three trials and the leg flexibility undex were then used to formulate the linear equation.



(a)



(b)

Figure 3 : (a) The front kicking experiment set-up [10] and (b) Flowchart on experimental protocol

2.3 Formulation of Linear Equations Using Regression Analysis

The next step is to formulate the linear equations based on the assumption stated earlier on which is the greater the kicking angles, the greater the leg flexibility index. To achieve the second objective, the regression analysis was employed. In this case study, the mean kicking angle is assumed as the independent variable whereas the dependent variable is the leg flexibility index. The regression analysis was a straightforward process (as shown in Figure 4) and it was conducted by using Microsoft Excel. The evaluation of the formula generated from the regression analysis was further analysed using residual plot analysis.

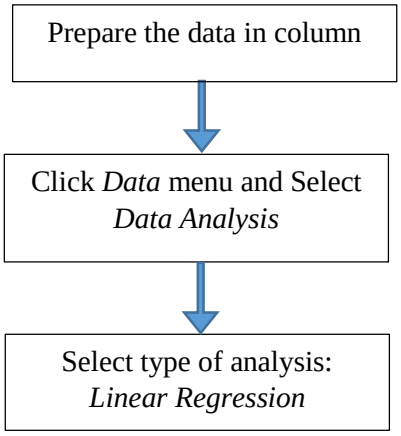


Figure 4: Simple regresion analysis process in Excel

3. Results and Discussion

3.1 Regression Analysis

The regression analysis had successfully produced two equations for silat athlete (Eq. 3) and non-silat athlete (Eq. 4) based on the linear assumption. Strong correlation between these two parameters can be seen from the coefficient determination, R^2 value. This result indicate tha these variables (leg flexibility index and mean kicking angle) have a statistically significant relationship. The R^2 value of non-silat athletes ($R^2 = 0.9472$) was slightly higher than the value of R^2 for silat athletes ($R^2 = 0.9088$) in which higher value indicates higher quality model. Nevertheless, both models show fairly decent models for the predictions of leg flexibility index.

- *Silat athlete*

$$y = mx + c$$
$$y = 0.0028x + 1.4516 \qquad \text{Eq. 3}$$

where,
gradient, m= 0.0028; y-intercept, c = 1.4516; coefficient determination, R^2 = 0.9088

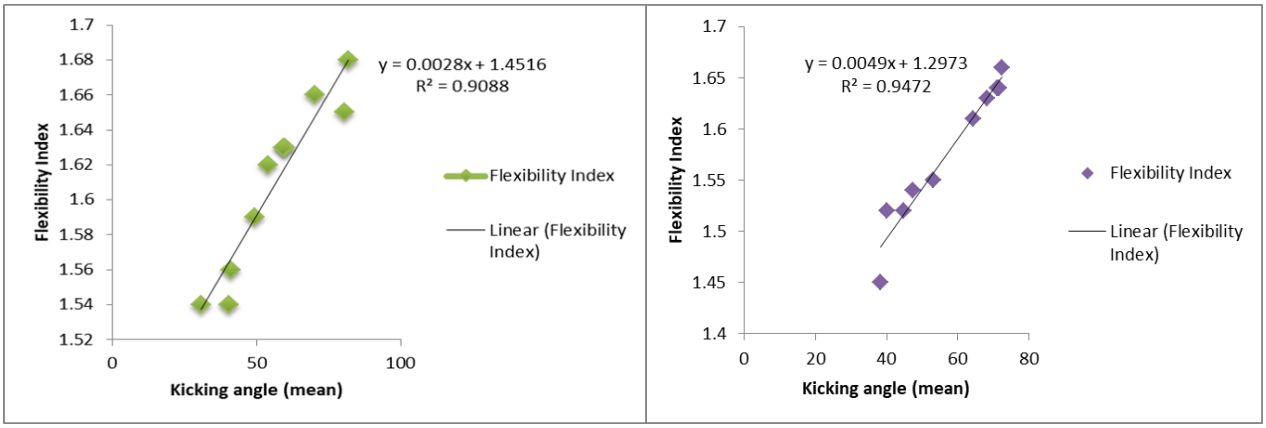
- *Non-silat athlete*

$$y = mx + c$$
$$y = 0.0049x + 1.2973 \qquad \text{Eq. 4}$$

where,
gradient, m = 0.0049; y-intercept, c = 1.2973; coefficient determination, R^2 = 0.9472

Meanwhile, Figure 5(a) and 5(b) illustrate the regression lines obtained from the leg flexibility index against mean kicking angle for silat athlete and non-silat athlete, respectively. From both graphs, it can be seen clearly that a higher kicking angle is associated with higher leg flexibility index. In other words, as the mean kicking angle increased, the leg flexibility index was observed to be increased. Thus, these

results verified the assumption made earlier on which is the greater the kicking angles, the greater the leg flexibility index.



(a) (b)

Figure 5 : Regression line of flexibility index against kicking angle for: (a) Silat athlete and (b) Non-silat athlete

3.2 Residual Plot

The residual values and the corresponding plots for the silat athlete and non-silat athlete are shown in Table 1(a) and 1(b) as well as Figure 6(a) and 6(b), respectively. The value of residuals were not specifically to be high or low in order to get the best models, but it is said to be corrected on average for all fitted values where it must be centered on zero throughout the range of fitted values. From the residual plots (Figure 6(a) and 6(b)), it can be seen that the residual values of both models were approximate to zero throughout the range of the fitted values. Therefore, these two equation models show how successful the predictive information is being accessed in the residuals by none is correlated with another variable.

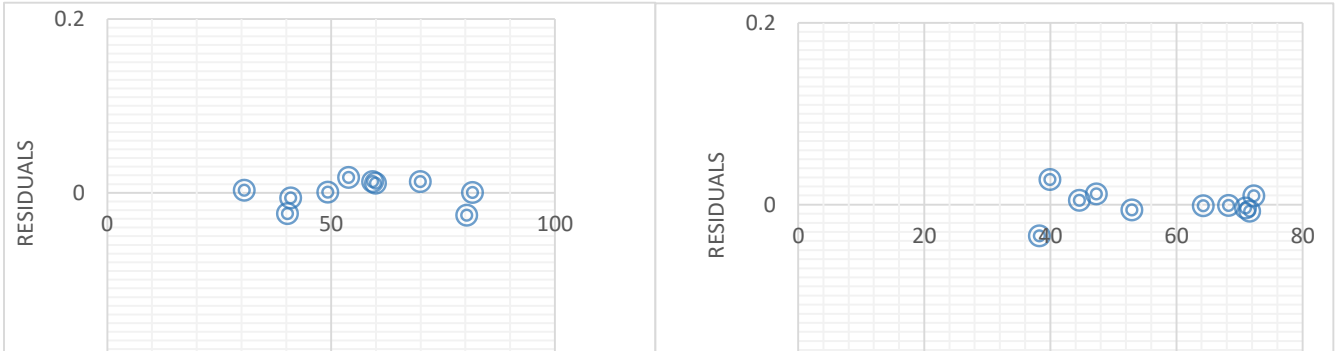
Table 1 : Observed, predicted and residual values for: (a) silat athlete subjects and (b) non-silat athlete subjects

Observed values	Predicted values	Residual
1.56	1.5664	-0.0064
1.59	1.5897	-0.000276
1.63	1.6196	0.0104
1.65	1.6765	-0.0265
1.68	1.6802	-0.000276
1.62	1.6028	0.0172
1.54	1.5645	-0.0245
1.63	1.6177	0.01227
1.66	1.6476	0.0124
1.54	1.5374	0.0025

(a)

Observed values	Predicted values	Residual
1.66	1.6517	0.0083
1.55	1.557	-0.007
1.52	1.4933	0.0267
1.61	1.6125	-0.0025
1.54	1.5292	0.0108
1.63	1.6321	-0.0021
1.64	1.6452	-0.0052
1.45	1.4851	-0.0351
1.52	1.5161	0.0039
1.64	1.6484	-0.0084

(b)



(a) (b)

Figure 6 : Residual plots obtained for: (a) silat athlete subjects and (b) non-silat athlete subjects

3.3 Further Discussion

According to [8], if the subject has a flexibility index higher than 1.15, he is then considered as having a good flexibility. However, in this research, the flexibility index formula (Eq. 1) has been modified to consider the leg flexibility (Eq. 2) only and thus, further discussion on the flexibility index trend comparison between previous study and this study was not able to be discussed here since the main parameter used in this study was no longer flexibility index (Eq. 1) but instead the leg flexibility index (Eq. 2). Moreover, the measurement of how good the subject's flexibility was not covered in this research too and therefore, this is subjected to be highlighted in the future works.

The main purpose of conducting the regression analysis is to determine the linear relationship between the mean kicking angle and the leg flexibility index by assigning mean kicking angle and leg flexibility index as the independent variable, *x* and the dependent variable, *y*, respectively. The dependent variable is the factor that is going to be predicted while independent variable is the factor that will have an impact on the dependent variable. Eq. 3 and Eq. 4 had shown strong linear relationship between mean kicking angle and the leg flexibility index based on the high R^2 values as well as very low residual values as indicated in Figure 6. The resulted findings verified the hypothesis of the study which is the greater the kicking angle, the greater the leg flexibility index.

Higher leg flexibility index can contribute to a better front kicking performance for silat athletes. Since the developed tool was initially recorded the kicking angle, the coaches will be able to predict the leg flexibility of the silat athlete without taking the true leg measurement by employing Eq. 3. Meanwhile, Eq. 4 will be beneficial for regular persons who enjoy joining any combat sport for leisure purposes but wishing to know their leg flexibility index provided that they know their kicking angle values. Nevertheless, the equation models obtained are stayed true and applicable so long that the same prototype device is used to measure the kicking angles and so this indicate as the main limitation of the study.

4. Conclusion

In conclusion, all objectives that were set in the beginning of the research were successfully achieved. The correlation equation models between flexibility index and mean kicking angle by means of regression analysis method had been successfully obtained by using twenty subjects from silat athletes and non- athletes. The findings obtained from the regression analysis showed that the model from non-silat athlete has higher accuracy than of the silat-athlete based on the R^2 value. However, both equation models were still acceptable for predictions of flexibility index owing to the very low residual values. In the future, it is suggested that more subjects should be recruited to ensure that the evaluation of models predictions are more reliable. Besides that, the validation experiment using sit and reach test for evaluating the performance of the obtained models as well as machine learning implementation in Matlab for producing prediction models can be carried out.

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