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BIOMECHANICS ANALYSIS AND OPTIMIZATION OF INSTEP KICKING: A CASE STUDY TO MALAYSIAN FOOTBALLER

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ABSTRACT

This study will focus on the biomechanics analysis on the professional soccer players as well as to identify and investigate problems regarding their kicking action. Analysis would be made by studying on kicking technique using the instep kick which takesicloser look at a professional player in the malaysian league classified at underage of 23 years. In this context, biomechanical analysis has been used to identify the variable such as velocity, acceleration, distance and the angle of the knee whether it would influence the players kicking force. Data management and analysis adapting Silicon Pro Coach software whereas statistical analysis was carried out using Minitab's software. Image of instep kicking was captured during the study and is useful to get the data of the kicking action for the analysis purpose. Based on the findings, the variables was identified to be significant to the force model besides succeeded to obtain the force equation model. Through readings gathered from the Taguchi's method we managed to get the optimum kicking value. Based on the findings, the velocity and distance was identified to be significant with the force model. The highest average force of kicking is 5879.60N that is on the highest average velocity 8.2m/s with distance kick that hit until 47.85m. From Taguchi's method, the optimum distance and velocity namely respectively as much as 0.163m and 8.035m/s can give the highest optimal force to the reading of 5602.12N.

***Keywords**:* Acceleration, Force, Velocity, Distance, Angle, Biomechanics

INTRODUCTION

Soccer sport in Malaysia has got far to reach the targeted achievement. This phenomenon had put pressure to researchers to study on the performance improvement to soccer players. The instep kick has been chosen for analysis because no research has been conducted on skill among Malaysian players and also because of our preference to look into the kicking skill of football. The biomechanics analysis was made for the soccer players to identify and investigate their kicking action. In this study, the quantitative biomechanics analysis was introduced. The study was executed by quantitative measurement as well as quantitative biomechanics analysis.

Biomechanics is the study on structure and function of biological systems by means of the methods of mechanics (Hatze, 1974). Biomechanics includes the study of all living things, plant and animal for animal bio mechanics investigate only on animals as the subjects of the study, human biomechanics which touched only on human-being, and exercise and sport biomechanics includes only humans involved in exercise and

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sport (Luhtanen, 1988). The biomechanics of kicking in the soccer sport is particularly important for guiding and monitoring the training process. Studies in the biomechanics of instep kicking have been focusing on numerous variables in different populations, all seek for the establishment of the optimal variables or variables that might be most predictive of success in instep kicking, with success being most typically defined by resultant to the ball velocity. Biomechanical techniques can be used for any sports, and soccer in particularly, useful to define the characteristics of skills, to gain the ground of the mechanical effectiveness of their execution and to identify the factors underlying their successful performance. This knowledge and understanding can assist to enhance the learning and performance of those skills.

Instep kicking has been studied from the youngest age groups to the group of seasoned professionals (Asami and Nolte, 1983; Luhtanen, 1988). The instep kick generally uses the laces of the shoe to strike the ball. When the player kick with the right foot, the approach should be from behind and to the left-side of the ball; meanwhile the approach is made from behind and to the right of the ball when kicking with the left foot. The full instep kick has been biomechanically studied in detail defining its typical components including the foot/ball contact phase (Barfield, 1998). This phase is characterized as a mixture of an impact-like and a throwing-like movement (Tsaousidis & Zatsiorsky, 1996). Due to the relatively short contact time for about 9 ms for instep kicking (Shinkai et al., 2009), the success of the kick, ball velocity and ball accuracy, is already determined by the at ball impact. Generally, successful kicks need to be fast and accurate, especially when kicks at the goal spot. Among the different instep kicking techniques the full instep kick is the fastest, followed by the inner and outer instep kicks (Neilson & Jones, 2005). In this case, the reduced ball velocities for the inner and outer instep kicking techniques are traded to ball spin achieved by off-centered foot/ball contact.

Powerful kicks are achieved through a high foot velocity and coefficient of restitution. Preliminary data indicates that accurate kicks are achieved through slower kicking motion and ball speed values. Success of an instep footballer kick depends on various factors including the distance of the kick from the goal, the type of kick used, the air resistance and the technique of the main kick which is best described using biomechanical analysis (Less & Davies, 1988). The distance, velocity and angle imposed kicking are the pertinent parameters involving the kicking activities where it can contribute to high impact to effectiveness of kicking (Kellis et al., 2004). Therefore, new aspects of footballer kick performance are being identified, including more details regarding the three-dimensional kinematics of the movement, joint-moments that drive the movement, mechanisms of footballer performance as well as various factors like age, gender, limb dominance and fatigue which affect footballer to kick biomechanically. The aim of the study was to examine recent findings on footballer kicking biomechanics and to identify new aspects that may be decisive for footballer kick performance (Nunome et al. 2002) noting that, the maximum speed of ball kicked and angular velocity relies on the turn age of the footballer is as the age increased (E.Manopolopoulos et al. 2004). The dominant limb as opposed to thedominant examined as bilateral capacity development is particularly important in skill in football such as instep kick (Mc Ginnis, 1999).

Taguchi Analysis

Taguchi method is one of the method complementing system methodology for efficient optimum design. Taguchi method perfection would complement gain factor at once. This method is in common in term of experimental design (design of experiment) where the taguchi design only lead blending balance experiment (orthogonal) which made

taguchi design more effective of factorial design fraction (fractional factorial design). Taguchi's approach is totally based on statistical design of experiments (Park, 1996), and this can economically satisfy the needs of problem solving and product or process design optimization (http://www.vkroy.com/up-doe.html). Two of the applications in which the concept of S/N ratio is useful are the improvement of quality through variability reduction and the improvement of measurement. The S/N ratio characteristics can be divided into three categories when the characteristic is continuous (Park, 1996):

a) Larger is better characteristic

$$\frac{1}{+}\frac{1}{+}\frac{1}{+}\ldots.$$

$$\text{MSD} = \frac{Y^2 \quad Y^2 \quad Y^2}{\frac{1 \qquad 2 \qquad 3}{n}}$$

b) Nominal is best characteristic

$$\text{MSD} = \frac{(Y-Y)^2+(Y-Y)^2+(Y-Y)^2+\ldots}{\frac{1 \quad 0 \qquad 2 \quad 0 \qquad 3 \quad 0}{n}}$$

c) Smaller is better

$$\text{MSD} = \frac{Y^2+Y^2+Y^2+\ldots}{n}$$

Where 1.

$Y_1, Y_2, Y_3 \ldots\ldots, Y_n$ is decision value something experiment

2. N is value number
3. Y_0 is target value

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Quality nature larger is better being chosen of this study as to analyze the level of ability decision on velocity and distance. This nature is chosen for making it possible to get the maximum distance and velocity in ankle contributing to the maximum force.

METHODOLOGY

Subject Selection

The subject has been selected is from professional soccer player with average heights of the Asian people. The subject delivered instep kicking by using the right leg. Most important thing was that subject has to be in good health during experiment because the kicking should be from self force. Height, weight, age and body size of the subject is part of the data analysis. The anthropometry data on lower limb of the subject were also taken.

Experimental Setup

The study was conducted on the field of National Sports Institute (ISN). Deflection marker was used on the lower limb of the subject for data recording of the analysis. Venue to perform experiment also would be fixed by using cones with the distance between cones is fixed to 1 meter. Position of the ball is put at the middle of cone. Figure 1 shows the study setup for subject delivered an instep kicking. Two cameras would be used for this study that have been place at the front and side view. The camera will focus on the lower limb of the subject when the subject started to kick to get a better visual. Data recording were done with video/picture using Sony video camera. This camera can analyse of movement from as fast as 0.02 seconds per frame.

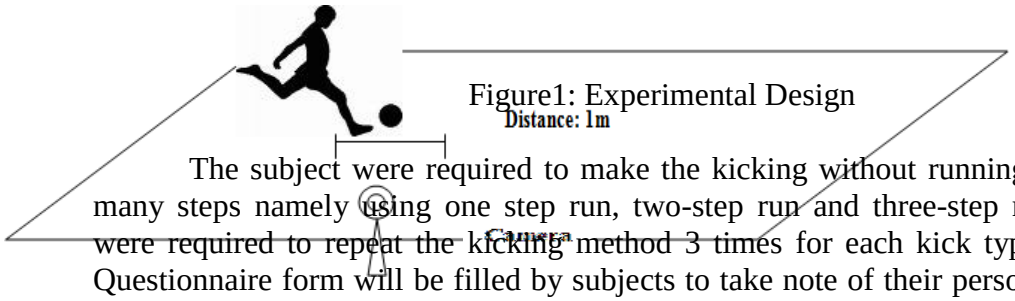

Figure1: Experimental Design

The subject were required to make the kicking without running which adopted many steps namely using one step run, two-step run and three-step run. The subject were required to repeat the kicking method 3 times for each kick type run step. The Questionnaire form will be filled by subjects to take note of their personal background. As this had taken place, subject would be undergone light exercise or warming up to avoid from occurrence of injury. The marker tape will be attached in subject lower body part that is on waist, knee and also ankle. Observation started when subject stops kicking the ball where posture of the leg from waist to knee and then to ankle was observed.

Data Analysis

The data were then analyzed by using the Silicon Coach Pro's software in order to simulate the linear trend between the variables on interest. For this particular case the multiple linear modeling equation was used to analysis the relationship between the distance, velocity and acceleration of kicking. Finally the Taguchi Method was adopted in order to obtain the optimum parameter of kicking for this particular study.

RESULTS AND DISCUSSION

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In this study, the subject delivered the instep kick by using the right leg with one step, two step and three step run with three times trial. Instep kicking activities were recorded by high speed camera video and later the image will be edited through still images according to the frame of every 0.02 per seconds interval before and after kicking. Figure 2 shows the angle where the subject started to kick and the angle when the ball is kicked was carried out. The reading angle also gained by using reading from every frame. Good kicking angle has been stated to be noted of the angular kick as 45°. This angle was measured from hip point, knee point and ankle point of the kicking leg.

Figure 2: Angle of Kick

Figure 3 shows the subject started to kick. The analysis was made during instep kicking with two step run which it will be analyzed by using software Silicon Pro Coach (Morrison J., 1997). Figure 3 also indicated the velocity relationship versus every time frame adopted and the distance when they are kicking. The force considered at ankle part due to the highest part hit on the ball as at the moment of kick contributed by the ankle if compared to knee part and waist. The maximum velocity produced in frame 4, which was before the foot impact and hit into the ball. The speed at the ankle when frame 4 is 8.20 m/s.

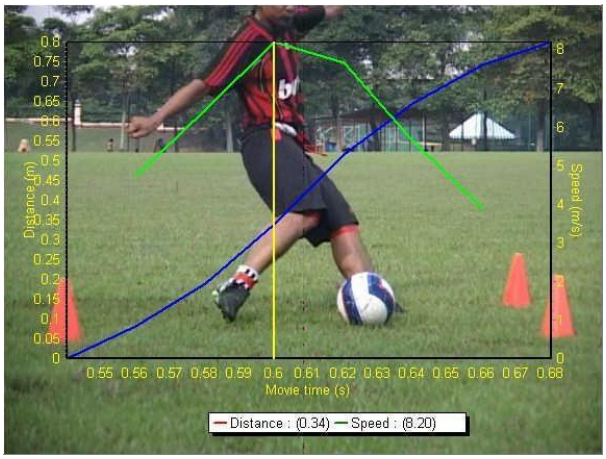

Figure 3:Velocity Versus Time

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Figure 4 shows the initial impact at ankle and ball part which the velocity at ankle will decrease as the consequent of the impact that occurred. Velocity at the moment is 7.67m/s, after the impact happened the velocity will decrease until subject completed his kicking action as the velocity value would be less until 0.53 m/s. The foot velocity reduction before the foot touching the ball would delivered high impact to the force inflicted by foot on ball. Kicking distance will be measured after set of kick been carried out and the ball dropped on the field recorded for its distance.

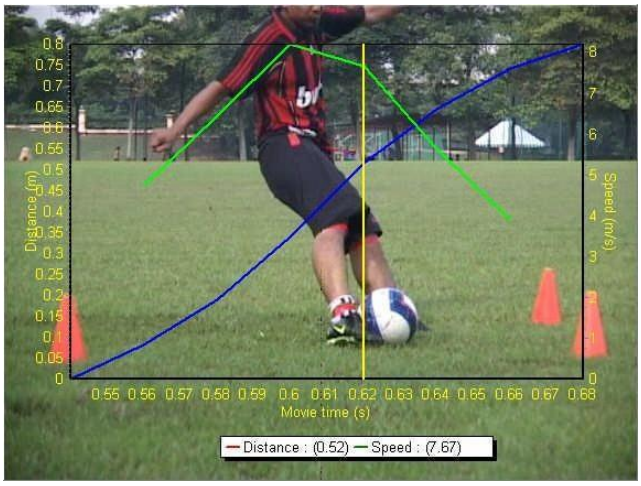

Figure 4: Velocity Versus Time

Table 1 presents, the distance, velocity and force for each run type when the subject delivering instep kick. From the table, the maximum velocity resultant, distance and force is found in three step run. The foot velocity before ball kicked is directly proportional with force imposed against the ball. In this analysis, force resultant of lower limb can be observed through Minitab (Farber, E., 1995) and Silicon Coach Pro's software. By taking note of the run expansion, the force resultant before ball kicked will be increased. The highest average force for right leg is 5879.60N and the highest average velocity is 8.2 m/s. Meanwhile from the Table 2, it was indicated the optimum velocity and distance on force for the subject using distinctive run type using the Taguchi Method. It was clear from Table 2, that the maximum optimum velocity, distance and force can be found in three step run. Kicking with running approach demonstrates higher ball speed values if compared to the static approach of kick. The optimum distance and velocity respectively noted as 0.163m and 8.035m/s, to give the optimal force for as much as 5602.12 N. Quality nature larger is better being chosen of this study as to analyze the level of ability decision on velocity and distance. This nature is chosen for making it possible to get the maximum distance and velocity in ankle contributing to the maximum force.

Table 1: The distance, velocity and force for each run type

Run type	Distance (m)	velocity (m/s)	Force (N)
One step	40.9	7.74	5549.85
Two step	45.8	7.88	5650.236
Three step	47.9	8.82	5879.6

Table 2: The Optimum Velocity, Distance And Force On The Subject Using Distinctive Run Type

Run type	Distance (m)	Velocity (m/s)	Force (N)
One step	0.1725	7.6345	5313.72
Two step	0.58	7.85	5349.35
Three step	0.163	8.035	5602.12

CONCLUSION

This study has shown that the highest average forces produced in force model analysis gained using three-step run. The highest average force received in right leg analysis also, as well as the highest average force noted to be 5879.60N and highest average velocity is 8.2m/s with the kicking distance achieved up until 47.85m. From this study using the taguchi method, it is found that the highest optimum force achieved from the three steps run. In three step run, the optimum distance and velocity respectively noted as 0.163m and 8.035m/s, to give the optimal force for as much as 5602.12 N. Success of an instep footballer kick depend on various factors including the distance of the kick from the goal, the type of kick used, the air resistance and the technique of the main kick which is best described using biomechanical analysis. The distance, velocity and angle imposed kicking are the important parameters involved in the kicking activities where it can contribute to the high impact of kicking effectiveness.

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