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Biomechanics Analysis for Dominant Leg During Instep Kicking

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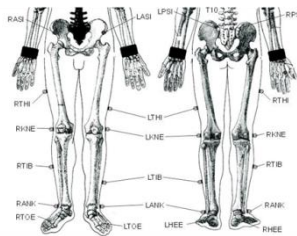[b]Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia

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Graphical abstract

Abstract

This paper presents the 3D biomechanics analysis on a soccer player during performing instep kick. This study was conducted to investigate the significant correlation within variables, such as: approach angle, distance of supporting leg from the ball and ball internal pressure with respect to knee angular velocity of the ball on the kicking leg. Six subjects from different categories were selected to take part in this study. Subjects selected are using dominant right leg and free from any injury. Subjects were asked to perform one step instep kick according to the setting for the variables with different parameter. Data analysis was performed using 3 Dimensional "Qualisys Track Manager". Statistical analysis was conducted by using Microsoft Excel 2007 software. Taguchi statistical analysis method was used to determine the composition of L_9 Orthogonal and larger noise to signal ratio (S/N). It was found the results of ANOVA analysis of P-values for all three parameters were lower than 0.05. It means that the approach angle, distance of supporting leg from the ball and the ball internal pressure have significant correlation with knee angular velocity.

Keywords: Distance; angle; biomechanics; pressure; soccer

Abstrak

Kertas persidangan ini mempersembahkan mengenai analisis biomekanik secara tiga dimensi dalam sukan bola sepak ketika melakukan tendangan kekura kaki. Teknik tendangan yang berkualiti merupakan aspek terpenting bagi seorang pemain bola sepak meningkatkan kualiti permainan. Teknik tendangan kekura kaki merupakan teknik tendangan yang kerap digunakan dalam sukan bola sepak bagi tujuan hantaran pendek dan tepat serta ketika melakukan jaringan. Kajian ini dijalankan bagi mengkaji pengaruh arah sudut larian dan jarak kaki sokongan daripada bola serta tekanan dalaman bola terhadap halaju sudut pada bahagian kaki yang menendang. Seramai enam orang subjek menggunakan kaki dominan kanan dan bebas daripada sebarang kecederaan dari pelbagai kategori telah dipilih sebagai subjek dalam kajian ini. Pengumpulan data dilakukan dengan mengambil gambar video 3 dimensi yang difokuskan pada bahagian bawah badan iaitu dari paras pinggang ke buku lali. Untuk tujuan ini, penanda akan dilekatkan pada bahagian bawah badan sebelum tendangan dilakukan oleh subjek. Analisis data telah dilakukan dengan menggunakan perisian 3 Dimensi Qualisys Track Manager. Bagi analisis statistik, perisian Microsoft Excel 2007 telah digunakan. Analisis statistik menggunakan kaedah Taguchi, susunan Orthogonal L9 telah direka bentuk dan keputusan kajian dianalisis berdasarkan purata nisbah isyarat hingar (S/N) dan analisis varian (ANOVA). Didapati nilai-P yang diperolehi bagi ketiga-tiga parameter daripada analisis ANOVA untuk nisbah S/N adalah kurang daripada 0.05. Ini menunjukkan bahawa faktor arah sudut larian, jarak kaki sokongan dengan bola dan tekanan dalaman bola mempunyai hubungan yang signifikan dengan kadar purata halaju bagi lutut.

Kata kunci: Jarak; sudut; biomekanik; tekanan; bola sepak

■1.0 INTRODUCTION

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. Hatze (1974) stated the biomechanics is the study on structure and function of biological systems by means of the methods of mechanics [1]. 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 sport [2].

Among different instep kicking techniques, full instep kick is the fastest, followed by inner and outer instep kicks [3]. Instep kicking has been studied from the youngest age groups to the group of seasoned professionals [2]. The full instep kick has been biomechanically studied in detail by defining its typical components including the foot/ball contact phase [4]. Length, speed and angle of approach are the three most important aspects of this preparatory movement which has a significant effect on soccer kick success [5]. The soccer ball is characterized by its mass, diameter, internal pressure and surface texture. A FIFA approved ball (i.e. size 5, ball pressure at 0.9 bars, and weight 0.44kg) was used in the experiments [6]. Another important aspect of kicking success is the placement of the support foot behind and beside the ball [7]. It has been suggested that the foot should land between 5 to 10 cm behind and 5 to 28 cm beside the ball [8]. McLean and Tumilty (1993) had suggested placement of a foot support approximately 30 cm to the side and 10 cm behind the ball [9].

Taguchi method of parameter design provides the design engineer with a method that systematically and consistently to determine the parameters of the optimum design in terms of performance and cost [10]. The objective is to select the best combination of parameters that control the product and the process is stable against the noise factors [11].

Successful kicks need to be fast and accurate, especially when kicking for shooting a goal. The distance, velocity and angle imposed during the kicking process are the three critical parameters involving the kicking activities that can contribute high impact to kicking effectiveness [5]. Further investigation is necessary to examine the optimum distance for the placement of the supporting leg, which could be proved a useful tool for trainers and coaches for improving soccer players' kicking performance [7]. Coaching experience, integrated with knowledge of a mechanical model for the desired performance is regarded as necessary for a coach to improve his/her players' performance [12]. Therefore, this study will be focusing on the biomechanics analysis with respect to the right leg of a soccer player besides to identify their kicking action and technique using the instep kick. In this research, the quantitative biomechanics analysis was performed. The study was executed by conducting quantitative measurement as well as quantitative biomechanics analysis.

■2.0 METHODOLOGY

2.1 Subject Selection

Six subjects from different categories such as professional, amateur and university. In addition, selected subjects in this study need to play at different positions, such as: striker, midfield and defender. They are using dominant right leg to perform the instep kick and free from any injury. Height, weight, age and body size of the subject is part of the data analysis. Anthropometric data of the subjects' lower limb were also taken.

2.2 Experimental Setup

The study was conducted in a closed door biomechanics laboratory. Equipments used were 5 units of high-speed video camera with a frequency of 200Hz and capable of analysing movement up to 0.005 seconds per frame. In order to get a good visual image, the camera will focus on subject's lower limb when he/she starts to perform the instep kick. This system was also equipped with a force plate that served as a force detector during

the experiments. As a target, a net was dispersed at a bar at the top of the laboratory. Deflection markers were used on the subject's lower limb for data recording and analysis.

2.3 Data Collection Activity

Subjects shall fill the questionnaire form with their personal background information. Having done that, subject would be asked to undergo some light exercises or warming up to avoid injury from occurring. Figure 1 show sixteen markers were attached at the lower limb parts of each subject's body.
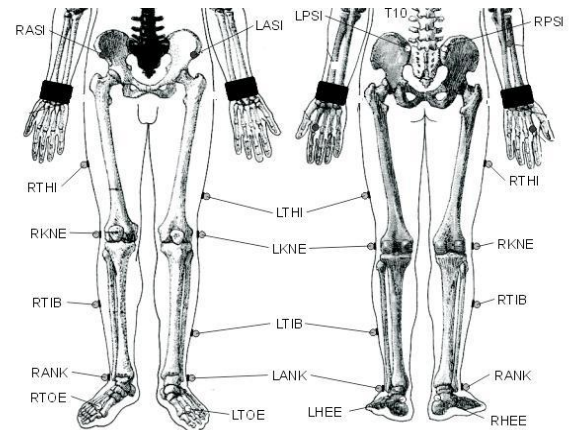

**Figure 1** Markers attached at the lower limb parts of subject's body

Subjects were required to perform the instep kick according to the arrangement for every variable with different parameter. In this experiment, each type of array will be repeated 3 times to obtain average values. The three parameters have been selected for every variable. Angles 0°, 45° and 90° has been chosen as parameter for approach angle. Parameters for ball internal pressures and distance of the supporting leg with the ball in this study were at: 0.4 bars, 0.6 bars and 0.9 bars and 5cm, 10cm and 15cm respectively. Figures 2 presents the experiment setup for this study.
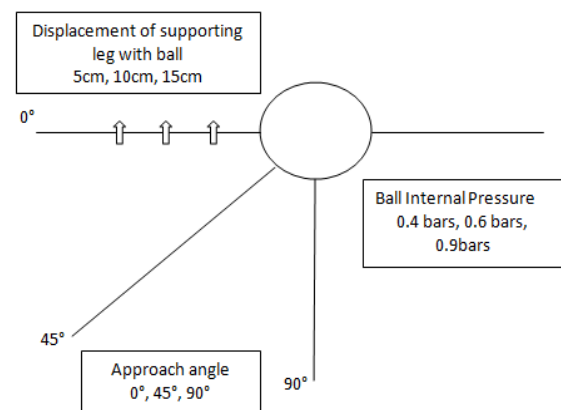
Figures 2 the experiment setup

2.3 Data and Kicking Analysis

Figure 3 presents the subject's body position and movement during kicking in 3 dimensional by using the *Qualisys Track Manager* software. Kicking in each frame will be analyzed according to the approach angle, ball internal pressure and distance of the supporting leg with the ball. Data were analyzed by using this software in order to simulate the linear trend between the variables on interest. Finally, Taguchi Method was adopted in order to obtain the optimum kicking parameter for this particular study.

Frame 1

Frame 2

Frame 3
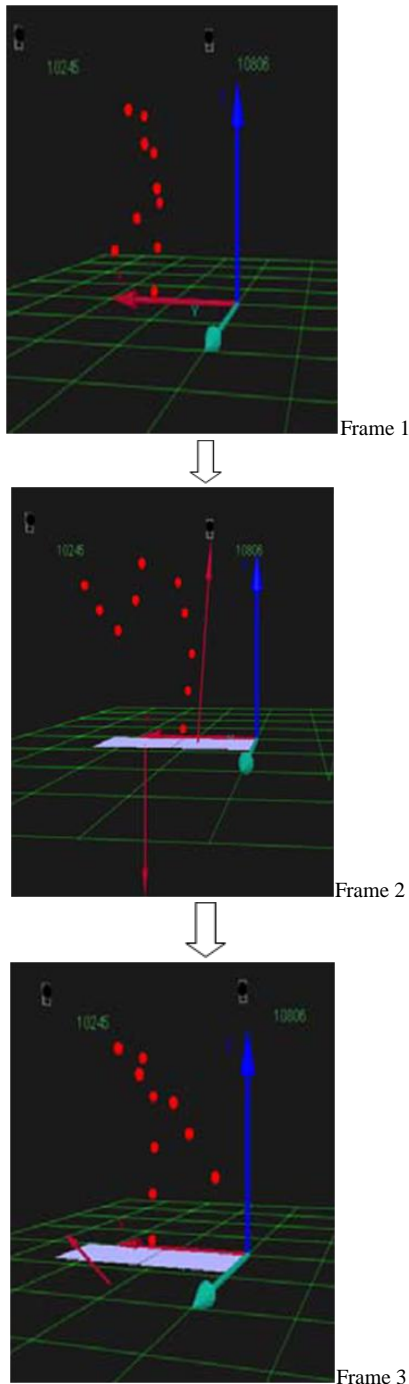
Figure 3   Kicking pictures in 3 dimensions

■3.0 RESULTS AND DISCUSSIONS

Table 1 show the variables and their selected levels for this study. These levels were selected based from results of past researches found in the literature. For the approach angle, selected level 0º was taken from Scurr & Hall (2009) and selected level range 30º - 90º were taken from Isokawa and Lees (1988), Scurr & Hall (2009) and Barfield *et al*. (2002)[13, 14, 15]. Hay (1993) and McLean &Tumilty (1993) had used the range of 5 - 15cm for the distance of the supporting leg [8, 9] and for the ball internal pressure, Andersen *et al*. (2008) had chosen the range of 0.4 - 0.9 bars [16]. The support foot of the soccer players is loaded several times during a soccer match. Kellis *et al*. 2004 examined kicks under different approach angles, with emphasis on the biomechanics of the support foot, and reported that the higher the approach angle, the higher the medial and posterior GRFs. He also suggested that kicks performed from an angle may induce significant loads to the knee joint structure of the support foot affecting kicking performance [5].

Table 1 Experiment variables and their selected level

Source	Experiment Variables	Unit	Level 1	Level 2	Level 3
A	Approach angle	(°)	0	45	90
B	Distance of supporting leg	(cm)	5	10	5
C	Ball internal Pressure	(bar)	0.4	0.6	0.9

Table 2 shows the result of analysis of variance (ANOVA) and also the percentage of contribution for all variables. From Taguchi analysis carried out, it was found that all variables, such as: approach angle; distance of the supporting leg; and ball internal pressure have strong relationships and significant to the knee angular velocity for all subjects. This can clearly be seen from analysis of variance (ANOVA) that the P-value of the three variables is less than 0.05. The percentage contribution also shows that the approach angle (95%) has a higher percentage significant to knee angular velocity. Isokawa and Lees (1988); Kellis *et al*. (2004) and Opavsky (1988) states that length, speed and angle of approach are the three most important aspects of this preparatory movement which has a significant effect on soccer kick success [5, 14, 17].

■4.0 CONCLUSIONS

Results of the study calculated by using Taguchi method statistically analysis showed that the three parameters, which consist of approach angle, distance of supporting leg from the ball and ball internal pressure were found to have significant effect in producing high quality instep kick. It was found that ANOVA   analysis   of   P-values for all   the three parameters were lower than 0.05. It means that the approach angle, distance of the supporting leg from the ball and the ball internal pressure have significant correlation with average knee speed.

Table 2 Voltage values and corresponding BAC values

Symbols	Variables	DF	Seq SS	Adj SS	AdjMS	F	P	Percentage of contribution
A	Approach angle(°)	2	114.092	114.092	57.0458	1915.50	0.001	95
B	Distance of the supporting leg (cm)	2	4.794	4.794	2.3968	80.48	0.012	4
C	Ball internal pressure (bar)	2	1.349	1.349	0.6743	22.64	0.042	1
Error		2	0.060	0.060	0.0298			0.00
Amount		8	120.293					100.00

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