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Application of Novel Inertial Technique to Compare the Kinematics and Kinetics of the Legs in the Soccer Instep Kick

by
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The kinematic and kinetic parameters of dominant and non-dominant legs examined with a new technology on 15 male, university soccer players in the field. A sensor module with special configuration of accelerometers placement, connected to a data logger, which attached to the shank and thigh, was applied to execute four instep kicks in the field. The angular velocity, linear velocity, angular acceleration and Z-axis linear acceleration ($p<0.005$) of the shank in dominant and non-dominant leg before impact were: 1970 ± 210, 1648 ± 300 °/s; 14.9 ± 3.0, 12.4 ± 2.6 m/s; 586.4 ± 121.9, 498.2 ± 160.4 rad/s^2; 5.7 ± 1.7 and 4.0 ± 0.9 gravity, respectively. The leg swing time, force (X) ($p<0.001$), torque, angular momentum, angular power and angular impulse ($p<0.05$) of the shank, for dominant and non-dominant leg, before impact were: 271 ± 48 vs. 263 ± 62 msec; 172.4 ± 46.6 vs. 68.7 ± 47.1 N; 133.2 ± 29.8 vs. 111.8 ± 34.9 N.m.; 5.3 ± 1.1 vs. 4.1 ± 1.0 kg.m^2/s; 2443 ± 666 vs. 1660 ± 790.1 W; 4.0 ± 0.9 vs. 3.3 ± 1.2 N.s., respectively. Even though there was lower shank angular velocity of the dominant leg compared with reported professional players, similar shape and gradient of the kicking pattern were found in the curves.
Key words: Accelerometer, Data Logger, Kinematic Analysis, Kinetic Analysis

Introduction

This study observed various biomechanical techniques in providing essential knowledge of mechanisms for enhancing performance and learning of sports skills (Lees & Nolan, 1998). In this regard, optical motion analysis systems, such as videography, photography, cinematography and opto-electric techniques, provided visual and indirect methods for measuring these parameters. In contrast with videography, inertia sensors are characterized by attaching sensors to the subject's body itself, which are based on the local coordinate system, as opposed to the global coordinate system (Y. Ohgi, 2006). Optical motion analysis systems are, however, expensive, bulky and not portable. Moreover, their installation and calibration is time consuming and professional staff needed. In addition, the output data require digitisation and smoothing before process and analysis. In videography methods, application of some filtering techniques may significantly alter the displacement signals by cutting the high frequency components and leading to underestimation of the true displacement, velocity and acceleration patterns during football impact (E. Kellis & Katis, 2007). However, these systems are preferred in restricted and controlled laboratory environments.

Soccer is the most popular sport in the world. A well-executed kick at goal is important in soccer to achieve high ball speed, as this gives the goalkeeper less time to react. Speed of the ball depends on the speed of the foot before impact and the mechanics of the collision between the foot and the ball (Dorge *et al.*, 2002). During the kicking movement, the segments of the kicking leg moves by rotating about an

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imaginary axis of rotation that passes through the proximal joint of the segment (Dorge *et al.*, 2002), and knee extension has the largest contribution to the final speed of the foot in soccer kicks (Levanon & Dapena, 1998).

The instep kick in soccer has been intensively investigated in male and female (Barfield *et al.*, 2002; Shan *et al.*, 2005) players because it involves high linear and rotational velocity of the foot to produce high velocity of the ball. The instep kick determines the effectiveness of the transfer of foot velocity to the ball, as the shank goes through a high linear and angular acceleration (Barfield, 2000; Lees & Nolan, 1998). It also generates the large force necessary for taking a shot at goal from a distance or when making a long pass (Luhtanen, 2005). Many studies attempted to unravel the complexity of this kick by 2-D and 3-D videography methods (Asai *et al.*, 2002; Barfield *et al.*, 2002; Dorge *et al.*, 2002; Levanon and Dapena, 1998; Nunome *et al.*, 2002; Nunome *et al.*, 2006a; b; Rodano and Tavana, 1993; Shan and Westerhoff, 2005; Van Deursen and Klous, 2001; Vaverka *et al.*, 2003) to measure the high kinematic parameters of instep kick.

The soccer players usually kick with a higher speed and more accurately with their dominant leg than with their non-dominant leg (Van Deursen & Klous, 2001). In professional soccer players, equal kicking performance for both legs is desirable (Van Deursen & Klous, 2001). The advantage of "two-footed" players has been shown through several studies of soccer matches (W.R.; Barfield, 1995; Nunome *et al.*, 2006a).

Understanding the biomechanics of kicking is important for guiding and monitoring the training process (E. Kellis & Katis, 2007). To understand the leg swing kinematics and kinetics of the dominant and non-dominant leg it is necessary to investigate the three-dimensional aspects of the biomechanical parameters.

Accelerometers are sensors that measure the linear acceleration acting along their sensitive axis (Mathie *et al.*, 2004). Accelerometry offers a practical and low cost method of objectively monitoring low range human movements (Aminian *et al.*, 1998; Aminian and Najafi, 2004; Aminian *et al.*, 2001). A combination of accelerometers and angular rate sensors (gyroscopes) showed to be applicable in low range movements. These sensors, together with a portable data logger, have been used to monitor physical activities (Bussmann *et al.*, 2000; McMillan *et al.*, 2005; Yoshifumi Inoue and Takeyoshi Yumiba, 2003), gait analysis (Kavanagh *et al.*, 2006; Scapellato *et al.*, 2005; Willemsen *et al.*, 1990), clinical investigations related to fall risk in the elderly (Cho & Kamen, 1998; Najafi *et al.*, 2002), orthopaedic outcome (Jaecques *et al.*, 2003), in walking (Foster *et al.*, 2008) and some sport performances (Davey *et al.*, 2005; Y.; Ohgi *et al.*, 2002). However, this combination is not capable of measuring high angular kinematics in most sports. Accelerometers have become the preferred choice in human movement detection and monitoring as a continuous, unobtrusive and reliable method (Godfrey *et al.*, 2008). Most accelerometers bandwidth and frequency response are selectable in the electronic design.

A common problem in application of inertial sensors, or any skin-mounted sensor or marker, is the signal distortion or artifacts caused by the vibration of the skin and soft tissues (Forner-Cordero *et al.*, 2008). The skin-mounted accelerometer should firmly attach to the skin with a preload compressing the soft tissue and increasing the stiffness of the sensor attachment, in order to obtain accurate measurements (Saha and Lakes, 1977). Physical damping and the natural frequencies with the soft strapping were significantly smaller than those with the hard strapping in the Forner-Cordero study. Concluding from the past studies, hard strapping of the sensor module mounted on shin guard in this study to the mid-front of shank seems to have the least artifact during high frequency measurements of instep kick.

Soccer instep kick is an example of high angular kinematic and high impact movement in sporting activities. In a recent study by Nunome *et al.*, high-speed cameras were used to study the instep kick. It was reported that due to the inadequacy of the sampling rate of the cameras, coupled with the accompanying filtering techniques, values obtained for the instep kick in the past might not accurately replicate the observed kinematic parameters of the instep kick (Nunome *et al.*, 2006a; Nunome *et al.*, 2006b). This researcher, therefore, concluded that there is a need to find other ways for accurately measuring the instep kick. Hence, in this research a novel method was used to measure the kinematics of the instep kick. The purpose of this study was to determine whether there are any differences in the kinematics and kinetics of the dominant and the non-dominant leg in young, male university soccer players. Kinematic parameters of the shank, including linear and angular acceleration in three axes, linear and angular velocity

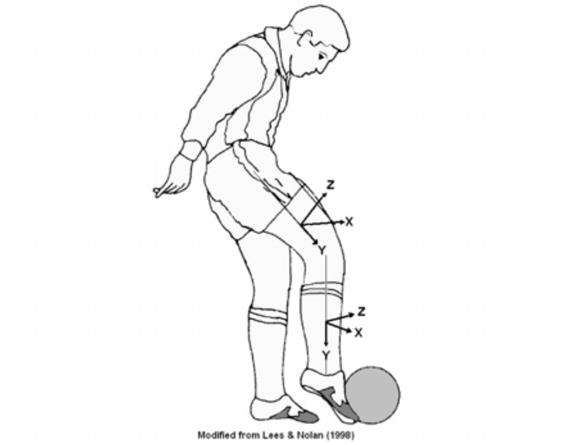

Figure 1
Inertial axes of sensor module and data logger

Figure 2
Attachment of the sensor module and data logger to the subject

in two axes, leg swing time, as well as linear acceleration of the thigh in three axes were studied. Kinetic parameters of the shank, such as torque, angular momentum, angular power, angular impulse and force of the shank during an instep kick, as well as thigh force were computed.

Materials & Methods:

In this study, a novel sensor module and data logger (Meamarbashi, 2009), which is applicable in the field, was implemented to measure the high rotational and linear kinematics of the shank, as well as linear kinematics of the thigh during execution of instep kick. The novelty of this system was based on application of accelerometer sensors in a specific configuration in the field of sports biomechanics.

Segment coordinate system was exploited in this research (Figure 1). In the segment coordinate system, sagittal, frontal, and transverse planes are fixed within each segment, and each segment moves in three-dimensional directions (Zatsiorsky, 1998). Inertial axes of the sensor module and data logger are demonstrated in Figure 2.

Participants

Fifteen right-leg dominant male university soccer players within the age range of 20-22 years (20.8 ± 0.8), body mass 68.1 ± 8.7 kg and height 174.4± 7.9 cm were selected. Subjects were instructed to wear their own personal soccer shoes, sport shirt and short in the soccer field. The dominant leg was self-reported. Those with previous leg injury, pathology of the knee joint and pain in the lower limb or any cardiovascular problem were excluded from the study. Age, height, body mass and other anthropometric and inertial parameters are tabulated in Table 1.

Measurements

Anthropometric variables include height, body mass, thigh, shank and foot lengths measured before field study. The mass of each body segment, indirectly calculated from total body mass by using the method of Cheng *et al.* (2000), using the following formula:

Segmental mass = Total Body Mass × Proportional Percent of Body Mass

Four (4) FIFA standard (size 5) soccer balls (425 ± 5 gr.) were used and each ball's pressure checked with pressure gauge to be 11-13 pound per square inch (psi).

Equipment and software

A novel sensor module mounted on a shin guard (weight= 80 gr, dimensions= 23 × 2.3 × 2.5 cm) was fixed to the middle-front aspect of the shank with elastic bands and connected to the data logger. The data logger (weight= 70 gr, dimensions= 6 × 5.7 × 2.5 cm) was attached to the frontal mid-part of the thigh using an elastic band. Data was saved on a memory card at 130 Hz. After each kick, the correct placement of the sensor module and data logger was controlled.

Table 1

Descriptive statistics of age, anthropometric and inertial parameters

Parameter	Mean ± SD
Age (year)	20.8 ± 0.8
Body Mass (kg)	68.1 ± 8.7
Height (cm)	174.4 ± 7.9
BMI (km/m^2)	22.3 ± 2.7
Shank Length (cm)	46.4 ± 2.2
Shank Moment of Inertia (kg.m^2)	0.230 ± 0.04
Leg Mass (kg)	11.1 ± 1.4

Testing procedure

After 10 minutes warm-up, 4 instep kicks were performed by each leg at an approach angle of 45° from 3 - 4 meters distance from the ball. Kicks were performed from 5 meters away from an empty soccer goal with the instep of their foot. The subjects were instructed to kick as hard as possible without concern for accuracy with their dominant leg (right), with 1-minute rest given between the kicks. After 5 minutes rest, this procedure repeated with their non-dominant leg (left).

Analysis methods

After field study, data from the data logger's memory card was transferred to a PC by custom PC software and saved into database. The method by Cheng *et al.* (2000) was used to estimate the shank and foot mass for evaluating the moment of inertia in each axis. The mean acceleration values of each parallel axes (e.g., X1, X2) of the sensor module were used to calculate the linear acceleration of the shank. The initial instant of toe-off was distinguished base on angular velocity in the X-axis. Impact with the ball was determined by sudden changes in X-axis angular acceleration. Data for moment of impact was chosen one sample before the detected impact time, to avoid errors related to ball impact (Meamarbashi, 2007).

Kinematic parameters (i.e., linear accelerations, angular accelerations and resultant of angular velocity in XZ axes) were processed to calculate the kinetic parameters by using leg inertial parameters (shank mass + foot + shoe, leg mass, and shank moment of inertia). The kinematic and kinetic values were separated into three stages (i.e., data before, at the moment of impact and during ball impact).

Linear velocity of the shank was estimated from the numerical integration of 3-dimensional linear accelerations of the shank during the last phase of the kick, from toe-off until ball impact. Angular velocity in the X-axis (extension/flexion) and Z-axis (abduction/adduction) was extracted from the two-dimensional angular velocity of the shank, by using angular acceleration in the X and Z axes from the end of back swing until impact with the ball. Leg swing time was also estimated during this phase. Angular acceleration, angular velocity, torque, angular power, angular momentum, and angular impulse were calculated at the instant of impact with the ball. Maximum linear accelerations in three axes were calculated before impact and during impact with the ball.

Statistics

SPSS software (SPSS, Chicago, Illinois) was used for the statistical analyses (version 15.0). After processing the raw data, the results were transferred into an SPSS format for statistical analysis. Results reported as mean ± standard deviation (SD). All data were tested for normality using the Shapiro-Wilk's test, as well skewness for measuring bilateral symmetry and kurtosis for measuring the relative peak of the data (Altman, 1991; Vincent, 1999). Independ-

Table 2

Maximum linear kinematics of dominant and non-dominant legs before impact (Mean ± SD)

Parameter	Unit	Preferred leg	Non-preferred leg	t-test	Sig. (2-tailed)
Shank Linear Acceleration (X)	gravity	4.2 ± 1.1	4.1 ± 1.3	0.068	0.946
Shank Linear Acceleration (Y)	gravity	7.8 ± 1.5	7.5 ± 2.1	0.550	0.586
Shank Linear Acceleration (Z) **	gravity	5.7 ± 1.7	4.0 ± 0.9	3.257	0.003
Shank Linear Acceleration (XYZ)	gravity	7.7 ± 1.4	7.2 ± 2.0	0.889	0.381
Thigh Linear Acceleration (X) *	gravity	8.7 ± 1.6	7.3 ± 1.9	2.220	0.035
Thigh Linear Acceleration (Y)	gravity	4.0 ± 1.6	3.3 ± 1.3	1.209	0.237
Thigh Linear Acceleration (Z)	gravity	6.3 ± 1.6	5.3 ± 2.5	1.238	0.226
Thigh Linear Acceleration (XYZ) *	gravity	9.1 ± 1.5	7.3 ± 2.5	2.370	0.025
Shank Swing Time	msec	271 ± 48	263 ± 62	0.420	0.678
Maximum Shank Linear velocity (YZ)	m/s	13.8 ± 2.9	11.3 ± 2.4	0.386	2.530
Maximum Shank Linear velocity (XYZ)	m/s	14.9 ± 3.0	12.4 ± 2.6	0.369	2.436

Table 3

Angular kinematics of dominant and non-dominant legs (Mean ± SD)

Parameter	Unit	Preferred leg	Non-preferred leg	t-test	Sig. (2-tailed)
Shank angular velocity at the instant of impact in (X)	°/s	1865 ± 201	1498 ± 345.6	0.987	0.332
Shank angular velocity at the instant of impact in (Z)	°/s	516 ± 385	559.3 ± 375	1.479	0.150
Shank angular velocity (XZ axes) at the instant of impact *	°/s	1970 ± 210	1648 ± 300	3.035	0.005
Maximum shank angular velocity (XZ axes) during impact *	°/s	2085 ± 264	1778 ± 323	2.983	0.006

ent sample t-tests were applied to compare the differences between the biomechanical parameters of dominant and non-dominant legs. SPSS software used to draw best fit regression lines for the presentation of cumulative data are presented in Figure 3 and Figure 4.

Results

Levene's test showed equality between the variances of biomechanical parameters.

As expected, the participants produced higher linear and angular kinematics and kinetics with their dominant leg, which was the right leg for all participants.

Independent sample t-tests revealed that the resultant of shank angular velocity in XZ axes at moment of impact with the ball was significantly higher (p=0.05) in the dominant leg, as compared to the non-dominant leg. Similarly, the maximum resultant of shank angular velocity during impact (p<0.05), shank force in X-axis (p<0.001), thigh force in Y-axis (p<0.05) shank linear acceleration in Z-axis (p<0.005), thigh linear acceleration in X-axis (p<0.05) shank angular acceleration in X-axis (p<0.05), resultant of shank angular acceleration (XZ) (p<0.05), shank angular momentum (p<0.05) and angular power (p<0.05), were significantly higher in the dominant leg.

During impact of the foot with the ball, very high linear and angular accelerations were recorded, as presented in Table 7.

The time from toe-off of the kicking leg to ball impact was analysed, with time duration normalized to 100%. Figure 3 and Figure 4 illustrate the shape of changes in angular velocity of the shank during instep kick in flexion/extension plane before impact (Figure 3 and Figure 4).

The regression line represents the mean value at calculated time percent of shank flexion during back leg swing and shank extension after the back swing. Computed angular velocity in X-axis (extension/flexion plane) in Figure 3 and Figure 4 showed shank flexion started from zero percent time with a negative angular velocity, until the end of back swing at 67.4% of the time; followed by a swift shank extension, indicated by a positive angular velocity until the foot struck the ball. The maximum resultant of angular velocity at impact was 3.14 times (34 vs -11 rad/s) higher than that during back swing. End of back swing phase was detected by zero angular velocity in the X-axis of the shank (end of shank flexion).

Non-dominant shank flexion and extension showed similar patterns as the dominant leg (Figure 3). Maximum negative angular velocity of the shank at the end of back swing occurred at 66.8% of the time. In Figure 3, the maximum resultant of angular velocity at impact was 3.11 times (28 vs -9 rad/s) higher than that during the back swing.

Discussion

The advantage of videography is the study of multiple segments and ball speed. However, these techniques are image-based measurements, and considering indirect measurements in contrast with the current method that movements directly detected by

Table 4

Maximum angular kinematics of dominant and non-dominant legs at the moment of impact (Mean ± SD)

Parameter	Unit	Preferred leg	Non-preferred leg	t-test	Sig. (2-tailed)
Shank Angular Acceleration (X) *	rad/s2	578.8 ± 119.7	492.2 ± 159.8	2.841	0.008
Shank Angular Acceleration (Z)	rad/s2	187.4 ± 83.7	199.3 ± 124.1	-0.328	0.745
Shank Angular Acceleration (XZ) *	rad/s2	586.4 ± 121.9	498.2 ± 160.4	2.637	0.013
Shank Angular Acceleration (Y)	rad/s2	1304.0 ± 238.8	1357 ± 286.6	0.428	0.672

Table 5

Maximum linear kinetics of dominant and non-dominant legs before impact (Mean ± SD)

Parameter	Unit	Preferred leg	Non-preferred leg	t-test	Sig. (2-tailed)
Shank Force (X) ***	N	172.4 ± 46.6	68.7 ± 47.1	6.053	0.000
Shank Force (Y)	N	326.9 ± 82.7	310.3 ± 98.3	0.500	0.621
Shank Force (Z)	N	114.3 ± 47.4	130.6 ± 57.5	-0.845	0.405
Shank Force (XYZ)	N	321.5 ± 72.9	299.5 ± 99.0	0.693	0.494
Thigh Force (X)	N	957.7 ± 256.8	786.7 ± 211.2	1.992	0.056
Thigh Force (Y) *	N	417.8 ± 209.8	257.2 ± 152.5	2.399	0.023
Thigh Force (Z)	N	303.3 ± 159.8	345.3 ± 208.1	-0.620	0.540
Thigh Force (XYZ)	N	992.3 ± 221.7	782.7 ± 235.9	2.508	0.541

sensors. Videography is light weight, small, portable, cheap, fast, robust, flexible, and adaptable to many other fields of sports. It can measure angular velocity up to ±100,000 °/s and linear acceleration up to 2,452 m/s^2 in Z axis and 981 m/s^2 in X and Y axes (Meamarbashi, 2007). However, to measure a multi-segment study, the instrument should be attached to each segment in a sensor network configuration.

Interestingly, additional information on angular acceleration obtained in the Y-axis (shank internal/external rotation) was not previously reported. The plausible reason for this might be due to technical difficulties inherent in the 2- and 3-dimensional videography techniques that did not allow for measuring the internal/external rotation of the shank (Levanon & Dapena, 1998).

Most of the previous studies on instep kicks have shown discrepancies in the results of angular kinematics when using 2-dimentional or 3-dimetional videography (Asai *et al.*, 2002; Barfield *et al.*, 2002; Dorge *et al.*, 2002; Levanon and Dapena, 1998; Nunome *et al.*, 2002; Nunome *et al.*, 2006a; b; Rodano and Tavana, 1993; Shan and Westerhoff, 2005; Van Deursen and Klous, 2001; Vaverka *et al.*, 2003). In 2-dimensional videography, movement is usually captured in a straight run-up from a position directly behind the ball in one plane. This gives lower kinematic and kinetic values as compared to the ball approach at angle of 30° to 45° (Isokawa & Lees, 1988). In 2-dimensional videography, the angled approach introduces errors. Dorge (2002) reported kinematic and kinetic parameters of seven skilled soccer players with non-angled approach during execution of instep kicks with the 2-dimensional cinematography technique. In contrast to the above, in the current method, the device attached to the shank and thigh directly measured the movements in three axes and were not impeded by the player's run-up approach. However, to our awareness, no direct measurement method was previously reported in soccer kicks.

Another disadvantage of videography is related to employment of smoothing filters, which cannot distinguish between true deceleration produced by the impact with the ball and spurious acceleration signals, due to noise in the data (Nunome *et al.*, 2006b); and the data can also be over-smoothed near impact with the ball (Levanon & Dapena, 1998). Unfortunately, this problem was not acknowledged in most of the previous studies on kicking, and when acknowledged, it was not dealt with properly (Levanon & Dapena, 1998; Nunome *et al.*, 2006b). Culminating from this, the current method, therefore, has the advantage of using a direct mounting method to record the angular velocity and angular acceleration at the moment of impact with the ball, and no filtering method applied.

In this study, the moment of impact was detected by a sudden change in the X-axis angular acceleration of the shank near to shank maximum angular velocity in X-axis. Impact time in most cases was seen before maximum shank angular velocity, and this finding is in agreement with the hypothesis pro-

Table 6

Maximum angular kinetics of preferred and non-preferred legs at the instant of impact (Mean ± SD)

Parameter	Unit	Preferred leg	Non-preferred leg	t-test	Sig. (2-tailed)
Shank Torque (X)	N.m	43.8 ± 23.5	44.5 ± 23.2	-0.084	0.934
Shank Torque (Z)	N.m	131.4 ± 28.6	110.3 ± 34.3	1.830	0.078
Shank Torque (XZ)	N.m	133.2 ± 29.8	111.8 ± 34.9	1.810	0.081
Shank Angular Momentum *	$Kg.m^2/s$	5.3 ± 1.1	4.1 ± 1.0	3.081	0.005
Shank Angular Power *	W	2443 ± 666.0	1660 ± 790.1	2.937	0.007
Shank Angular Impulse	N.s	4.0 ± 0.9	3.3 ± 1.2	1.879	0.07

Table 7

Maximum linear and angular kinematics of dominant and non-dominant legs during impact (Mean ± SD)

Parameter	Unit	Preferred leg	Non-preferred leg	t-test	Sig. (2-tailed)
Shank Angular Acceleration (X)	rad/s^2	3095 ± 2231	2782 ± 2283	0.380	0.707
Shank Angular Acceleration (Z)	rad/s^2	1719 ± 736.5	1290 ± 688.2	1.650	0.110
Shank Angular Acceleration (Y)	rad/s^2	4278 ± 7972	2178 ± 1083	1.011	0.321
Shank Linear Acceleration (X)	gravity	14.1 ± 6.6	12.2 ± 4.9	0.914	0.369
Shank Linear Acceleration (Y)	gravity	22.9 ± 7.1	21.7 ± 9.6	0.389	0.700
Shank Linear Acceleration (Z)	gravity	33.8 ± 7.5	29.6 ± 7.6	1.502	0.144
Shank Linear Acceleration (XYZ)	gravity	37.8 ± 7.1	32.6 ± 7.3	1.983	0.057

posed by Meamarbashi (2007), Nunome *et al.* (2006b) and Dorge *et al.* (2002), who reported that impact with the ball occurred mostly before maximum angular velocity was attained. There was no difference in shank angular velocity in the Z-axis, implying that shank abduction/adduction was not significantly different during leg swing in the two legs.

Current results showed angular acceleration of the shank during impact with the ball in three axes were higher in the dominant leg, as compared with the non-dominant leg. Similarly, linear acceleration of the shank during impact in Y- and Z-axes were higher in the dominant leg. These findings could be related to lower muscle coordination and/or lower stiffness of the non-dominant foot during impact with the ball.

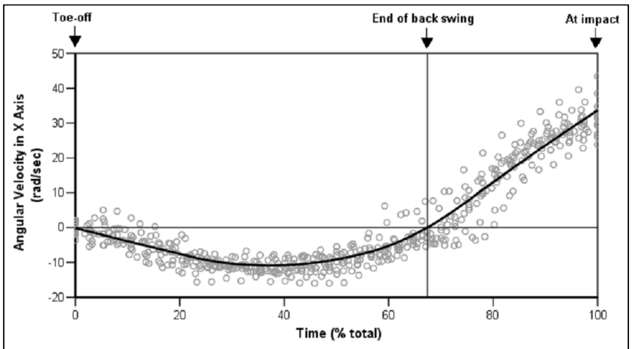

Figure 3

Preferred shank (right) angular velocity in X-axis (rad/s) obtained from fifteen subjects

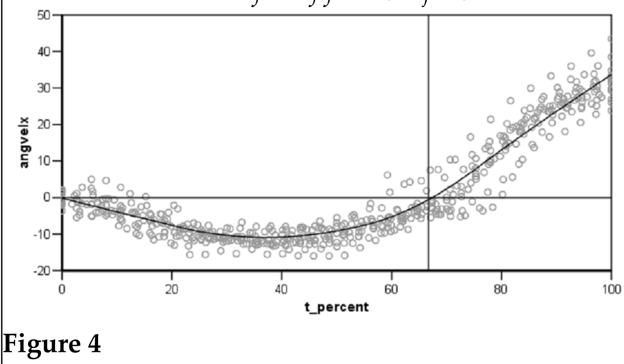

Figure 4

Non-dominant shank (left) angular velocity in X-axis (rad/s) obtained from fifteen subjects

Similar with Dorge *et al.* (2002) and Nunome *et al.* (2006a), angular velocity of the dominant leg was significantly higher than the non-dominant leg. Angular velocity in the X-axis of the dominant shank obtained 1911.2 ± 241.6 °/s or 33.3 ± 4.2 rad/s, which was comparable with the reported value of 2257 ± 246 °/s or 39.4 ± 4.3 rad/s by Nunome *et al.* (2006a), using 3-dimensional cinematographic technique at 200 Hz from the instep kick of five highly skilled soccer players (age 16.8 ± 0.4 years; body mass 70.6 ± 7.2 kg; height 176.2 ± 6.1 cm). In yet another publication, Nunome *et al.* (2006b) reported shank angular velocity of 2051 ± 264 °/s (35.7 ± 4.6 rad/s) on nine experienced male soccer players (age 27.6 ± 5.6 years; body mass 74.5 ± 8.2 kg; height 175 ± 6 cm). Culminating from these findings it would appear that the higher results obtained in the two reported studies could be related to the high level of soccer skill sets. In this study, results of angular velocity at the moment of impact did not significantly differ from previous results of Meamarbashi (2007). Meamarbashi (2007) studied 30 male Malaysian university soccer players (age 23.2 ± 4.5 year; body mass 65 ± 11.3 kg; height 167.5 ± 6.3 cm; right-leg dominant) performing four instep kicks at an angle of 45º to 60º with the right leg (X-axis: 1921.3 ± 166.4 °/s; Z-axis: 487.6 ± 151.7 °/s).

Our results of computed shank angular velocity in the X-axis before impact were compared with the widely accepted report on angular velocity of the leg, by Nunome (2006a). This researcher reported graphs of thigh and lower leg angular velocities before impact, but not after impact. The maximum angular velocity of the leg during back swing, reported by Nunome (2006a), seems comparable with the graphs obtained in the present study (Figure 3 and Figure 4). Additionally, there were similarities between the shape and gradient of the curves before impact in the current study (Figure 3 and Figure 4) and that of Nunome (2006a) and Kellis et al (2004). If all subjects had had the same level of skill, then lower variations would be speculated.

Conclusion

The primary objective of this study was to evaluate the differences between kinematic and kinetic parameters of the dominant and non-dominant leg during soccer instep kick by a cheap and quantitative method on the soccer field. Results revealed significant differences of biomechanical parameters between the two legs at the moment of impact and during impact with the ball.

This approach is in contrast to the current high-tech videography systems that are expensive, bulky, time-consuming and cumbersome. The current technique offers a relatively cheap and affordable device for coaches to use in the field, and quickly assess the technique performed by the soccer players and get immediate feedback for skill correction. Application of this data logger is not limited to soccer and can be use in many other sporting activities, such as Rugby, American football, etc., to evaluate the player's right and left legs in the field. Coaches are typically very interested in evaluating all members of a team in the least amount of time (Tanaka *et al.*, 2006), but motion analysis systems have failed to respond to this objective. This system proves very promising to apply in many sports to help coaches in the field.

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