A THREE-DIMENSIONAL KINEMATIC ANALYSIS OF THREE KICKING TECHNIQUES IN FEMALE SOCCER PLAYERS

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Human movement is a highly complex phenomenon that involves the interaction of a number of segments, muscles, and articulations of the human body. The motion of one segment will influence the motion of an adjacent segment because of the linked nature of the human body. Hudson (1986) suggested that a definite sequence and timing pattern must exist between these segments for successful performance to exist. How the segments interact and the timing pattern used during a movement is not well understood.

Kicking is a basic skill used in a variety of sport activities. Putnam (1983) has indicated that one component of kicking a ball is a correctly timed sequence of body segments. The sequence of segmental rotations for a kick has been labeled sequential with initial rotation at the pelvis, followed by the thigh, leg, and foot segments rotating about their respective axes. The soccer instep kick has been identified as a three-dimensional kicking motion (Huang, Roberts, & Youm. 1982), however, no research was found to validate this statement. Within a kicking pattern, various mechanical parameters may remain invariant despite a change in the purpose of the kick. Phillips (1985) stated that variability in some biomechanical parameters and invariance in others could aid in our understanding of the interrelationships between mechanical variables.

The specific purposes of this study were: (a) to describe the timing, sequence, and interaction of segments in a three-dimensional motion of a three-segment system, and (b) to investigate the invariance of mechanical parameters associated with three different soccer instep kicks.

METHODOLOGY

Seven female Division I intercollegiate soccer players volunteered as subjects. Demographic data on subjects (age: 20.1 ± 1.5 yrs; weight: 61.1 ± 2.8 kg; height: 151.8 ± 3.1 cm) were consistent with data found in the literature. Anthropometric data were obtained and 18 markers placed on specific bony landmarks of each subject for ease of analysis. Subjects were filmed from a 60° angle of convergence with two 16 mm high-speed cameras (LOCAM and PL-1) operating at nominal frame rates of 200 frames/sec. Subjects performed 2 practice trials followed by 2 mals of 3 different kicks (low drive, high drive, and maximum distance). The three kicks were filmed in random order by subject

Prior to filming of the subjects, a control object was filmed for application of the Direct Linear Transformation (DLT) method of three-dimensional (3D) analysis. After the films were processed, a NAC analysis film projector, Numonics Graphic Digitizer (2200). Packard Bell PC computer. and software (Zimmerman, 1989) were used in digitizing 18 data points. Data files were synchronized with the computer program SYNC (Yu, 1990). The synchronized x,y coordinates were entered into the DLT program to generate x,y,z coordinates. A second-order Butterworth digital filter (Winter. 1979) was used to smooth the displacement data. Instantaneous values for velocity and acceleration were calculated by the First Central Finite Difference Technique. A 3D model of the kicking leg was constructed with vector and mamx algebra to analyze the segmental angular displacements about the pelvis, hip, and knee of the kicking leg (see Figure 1). Information about the model can be found in Tant (1990).
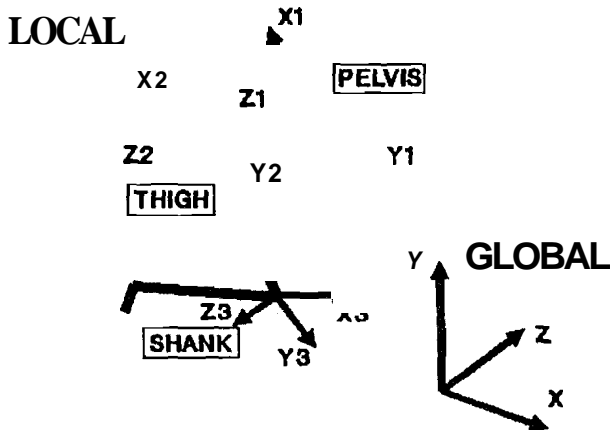

Figure 1. Three-segment lower body model

Temporal periods relative to **joint** action, timing delays between adjacent segments, and percentages of shared positive **contributions** between adjacent segments were investigated to **determine** segmental interactions.

RESULTS

Huang et **al. (1982)** suggested that considerable rotation of the pelvic girdle might **occur** during a **3D** soccer instep kick. **As** seen in Table **1,** range of motion (ROM) **for** pelvic rotation **(PLR)** varied from **18.3** degrees **for** the low drive **(LD)** and maximum distance (MD) **kicks** to **13.2** degrees **for** the high drive kick (HD). Increased hip flexion and extension (HFE) and **knee** flexion and extension (KFE) was noticed during the HD **kick.** Hip abduction and adduction (HAB) remained consistent among the three **kicks.** **Decreased** total time **(TTM)** and increased resultant ball velocities (RBV) **were** found during the low drive and maximum distance **kicks.**

Table 1
Angular Displacements of Three Soccer Instep Kicks

Variable	LD		HD		MD	
	M	**SD**	**M**	**SD**	**M**	**SD**
PLR (°)*+	18.3	3.5	13.2	5.2	18.3	4.7
HFE (°)*	37.8	5.7	57.9	3.9	45.9	2.8
HAB (°)	19.1	3.1	18.3	2.1	17.2	2.9
KFE (°)*+	74.5	4.3	94.5	4.0	70.7	3.8
TTM (ms)*	152.0	2.3	165.0	3.5	158.0	2.7
RBV (m/s)*+	17.01	3.5	13.51	6.6	16.17	2.8

* $p < .05$ HD vs. LD   + $p < .05$ HD vs. MD

A one-way ANOVA with repeated measures revealed several significant differences between the angular displacements of the **3 kicks.** A Tukey post-hoc analysis indicated that PLR, HFE, KFE, TTM, and **RBV** were different from the HD and LD kicks. Additionally, differences between the HD **and MD** kicks were noticed in PLR, KFE, and RBV.

A proximal to distal temporal segmental sequence, pelvis (PEL), thigh (THI), and then lower leg (LLG), was exhibited in all **3 kicks.** The PEL and THI began forward motion simultaneously, approximately **2.8** ms delay for all **kicks,** as the LLG continued backward. **A** sequential delay was found between the PEL-LLG and the THI-LLG (between **70-77** ms delay) conmbuting to increased velocities. Between **15** to **25** ms prior to ball contact the PEL and THI slowed and the LLG continued to maximum angular velocity.

A one-way ANOVA with repeated measures revealed no significant differences (p < .05) between the relative timing of the segments of each kick (see Figure 2). As shown in Figure 3 no significance was indicated between the relative timing of the 5 different phases of the kick (maximum thigh back, maximum shank back, support heel contact, ball contact, and ball release).
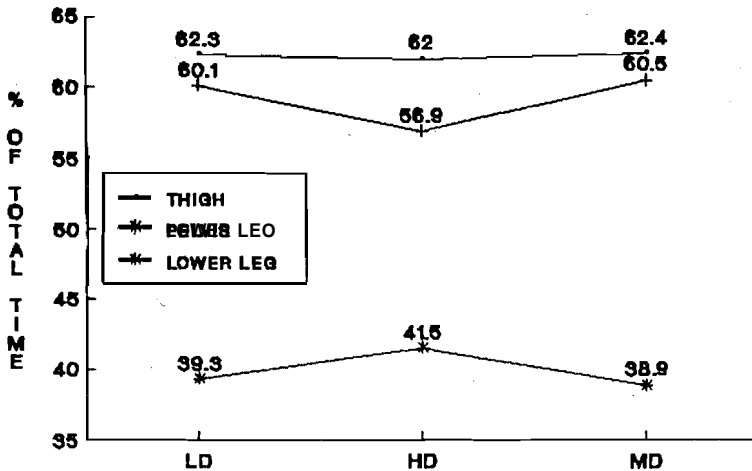

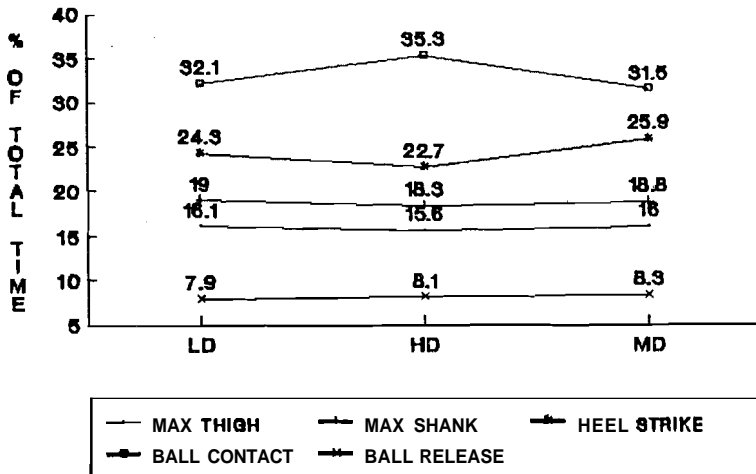Figure 2. Relative liming of the segments

Figure 3. Relative timing of the phases

DISCUSSION

The combination of increased PLR and a decrease in HFE and KFE, decreased the total movement time and produced the greatest resultant ball velocities. Female soccer players seemed to take advantage of increased pelvic width to produce maximum velocity. Small delays in timing and a large percentage of shared positive contributions indicated simultaneity between the PEL and THI. It appeared that the PEL and THI work as one unit to initiate the kick in a pushlike motion. A sequential pattern was observed between the THI and LLG because of large timing delays and small percentages of shared positive contributions. The soccer instep kick involves accuracy and velocity to produce a successful kick. The PEL and THI could aid in accuracy while the THI and LLG would generate maximum velocity. Because no significant differences were found in the relative timing of the segments it was found to be invariant indicating a common temporal structure for the soccer instep kick, regardless of type of kick.

CONCLUSIONS

Very little is known about the patterns of coordination among the limbs which serve as the foundation of skilled movement. Invariance and variability within biomechanical parameters could provide information about interrelationships between mechanical variables of a kicking motion. For a coach/teacher of soccer, it appears that the kicking technique of the soccer instep kick could be taught with basic anatomical and mechanical concepts with slight modifications based on the specific purpose of the shot.

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